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CONTENTS

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CURRENT EUROPEAN VETERINARY PROBLEMS

DISEASE CONTROL PROGRAMMES IN THE EUROPEAN COMMUNITY

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Traditionally the 12 Member States of the European Community (EC) have taken their own decisions on disease control. They decided not only the diseases which were of importance but where to use resources, the type and extent of control measures to be adopted and the public funding necessary. Each Member State determined its own import policy and decided what species or products could be imported from which countries and under what animal health conditions.

The Single European Act of 1986 specified that the Community should adopt measures with the aim of progressively establishing the internal market over a period expiring on 31 December 1992. The internal market would comprise an area without internal frontiers in which free movement of goods, persons, services, and capital was ensured in accordance with the provisions of the Treaty.

In 1988 the EC put forward proposals for the completion of the internal market which clearly indicated that animal health would not be exempted from the general principle of free movement within the Community. The overall objective was to achieve uniformly high standards of health and hygiene in all the Member States before 1993 to ensure that there was an environment in which animals and their products could move freely unless subject to disease restrictions. In order to achieve this aim, it was accepted that Community-wide rules were essential and all Member States should have a uniform approach to the problems of animal health including disease surveillance, notification, diagnosis, control and import policy.

The aim of this paper is to give an overview of the disease control programmes currently in place to ensure that the animal health and public health risks associated with the extensive movement of animals and their products into and within the EEC are minimised. The present position is reviewed in relation to disease notification, disease control procedures and veterinary controls.

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DISEASE SURVEILLANCE AND NOTIFICATION

The systematic collection of high quality, accurate and valid information on outbreaks of disease is an essential component of a surveillance system. This is of particular importance where there are no internal frontiers and there is a need for an early warning system to alert veterinary authorities to rapid changes in prevalence of existing disease and to identify outbreaks of previously unrecorded or exotic diseases. Rapid communication of disease information is also required.

Council Directive 82/894/EEC on the notification of animal disease within the Community became effective on 21 December 1982. A number of Directives in respect of health requirements for intra-Community trade in bovine animals and swine, fresh meat, fresh poultry meat and meat products were already in force and there was concern that the appearance or presence of certain contagious animal disease would present a risk to the Community. Rapid and accurate information on a Community-wide basis is essential for the application of the various protection measures provided for in Community rules.

Under this Directive, each Member State must notify all other Member States and the Commission within 24 hours of a primary outbreak of a disease listed in the Annex to the Directive occurring on its territory. Notifications are communicated in a coded format by telex. Each Member State must also notify the Commission directly on the first working day of each week of any secondary outbreaks of the specified disease which have been confirmed on its territory. The scope, contents and frequency of notification are laid down within the Directive but these may be temporarily modified in the light of the diseases concerned and their particular epizootological development.

The original Directive listed only 10 diseases but was expanded by an amendment in September 1989 which added a number of other diseases. These included African horse sickness (AHS), vesicular stomatitis, peste des Petitis Ruminants, Rift Valley Fever, lumpy skin disease, sheep and goat pox and infectious haematopoietic necrosis (IHN) of fish. In April 1990, Bovine Spongiform Encephalopathy (BSE) was added to the list of specified diseases as it was considered a serious new disease which could threaten Community livestock. Because of the characteristics of BSE, provision was made for weekly notification containing information required for secondary outbreaks.

Table 1. Diseases to be notified under Notification Directive 82/894/EEC (as amended)

Foot and Mouth Disease	Rinderpest
Pleuropneumonia	Bluetongue
Swine Vesicular Disease	Teschen
Classical Swine Fever	Sheep Pox/Goat Pox
African Swine Fever	Lumpy Skin Disease
Peste des Petits Ruminants	Rift Valley Fever
Vesicular Stomatitis	Fowl Plague
African Horse Sickness	Newcastle Disease
Bovine Spongiform Encephalopathy	Infectious Haematopoietic Necrosis

Table 1 shows the diseases which are notifiable to Member States and the Commission. Each of the individual Trade Directives such as 64/432/EEC on animal health conditions governing intra-Community trade in cattle and pigs specifies certain diseases such as brucellosis and tuberculosis which must be notifiable within Member States but without the requirement to notify the Commission or other Member States.

In addition to the diseases covered by the Notification and intra-Community trade Directives, a surveillance system is necessary to identify new or emerging diseases to ensure control measures can be taken by Member States and, where necessary, on a Community-wide basis. This 'safeguard' requirement is met in Council Directive 90/425/EEC where each Member State is required "to notify other Member States and the Commission of any outbreak in its territory in addition to an outbreak of disease referred to in the Notification Directive of any zoonoses, disease or other cause likely to constitute a serious hazard to animals or to public health". This is an important measure which will ensure that new disease or changes in prevalence and incidence of existing disease in Member States are notified so that the necessary action can be taken. Once reported, it would be incumbent on the Standing Veterinary Committee (SVC), made up of delegates from the 12 Member States and the Commission, to discuss the problem. The SVC on the basis of a majority vote might decide to support, amend or revoke the measures taken to control the disease in the Member State.

DISEASE CONTROL PROGRAMMES

Since 1986 considerable progress has been made in harmonising control measures for epizootic diseases. In October 1990, the EC confirmed that the measures necessary for completion of the internal market included stepping up operations to combat and control the main epizootic diseases threatening the Community, the object continuing to be the highest degree of harmonisation with regard to the protection of public and animal health within the Community. Any disease control programme must include rapid reporting and notification of disease, prompt investigation and diagnosis with the imposition of restrictions to control the spread of the disease without delay. Emergency measures must be introduced if new diseases occur and the extent of the restrictions will be determined by the type and severity of the disease. Control zones may be delineated to deal with widespread problems especially where high health status is to be maintained outwith such zones. Zoning already takes place in the case of classical swine fever (CSF), African swine fever (ASF), AHS and contagious bovine pleuropneumonia (CBPP). The EC has categorised diseases into 5 groups based on their characteristics and potential for control.

Disease control programmes

Group 1 diseases: This Group includes foot and mouth disease (FMD) and other diseases which, because of their potential for rapid spread and importance, must be identified and reported to the authorities. Control measures may be detailed in specific Directives.

No outbreaks of FMD have been recorded in the Community since 1990. The key single market measure was adopted in that year. This provides that the policy of vaccination against FMD practised in eight Member States at that time will be discontinued throughout the Community after 31 December 1992. Protection from the disease will involve slaughter and destruction of animals from affected herds with compensation to the owner. Emergency recourse to vaccination will be allowed where a major epizootic becomes extensive in a Member State. Strict rules will be applied and countries wishing to use vaccination will need to specify the geographical area, the way in which animals will be identified, the duration of the vaccination campaign and the movement controls for vaccinated animals and their products. A Community reserve of FMD vaccine has been established and measures taken to ensure that the quality and safety of the vaccine is satisfactory and would not pose a risk.

The control directive implementing EC measures for the control of CSF has been amended and updated. The amendments were necessary as serious difficulties had been experienced in eradicating the disease in those areas with a high density of pigs and in areas containing wild boar. The control measures now take into account current knowledge on the epidemiology of the disease, improved diagnostic methods, and the changes necessary for completion of the internal market. Specific changes include either modification of existing procedures or new measures covering control of disease in wild boar, cleaning and disinfection of infected farms, the use of crisis units, movement controls within protection and surveillance zones, diagnostic procedures and the use of emergency vaccination.

In addition to specific control Directives for FMD and CSF, 2 proposed Directives for the control of Newcastle Disease and avian influenza are also under discussion. In all cases these Directives detail measures to eradicate certain diseases and provide for uniform control procedures based on the concept of infected premises, 3 km prohibition zones and 10 km surveillance zones. Other diseases in this group would be dealt with in a similar way. Additional controls are detailed in the Veterinary Checks Directive (90/425/EEC) which contains an Annex listing 17 diseases which are subject to mandatory emergency action with territorial restrictions. Susceptible animals or their products must not be moved from holdings, areas or regions which are subject to restrictions as a result of suspicion or existence of one of the diseases referred to in this Annex.

Group 2 diseases: Contagious diseases such as brucellosis or tuberculosis which are notifiable on a herd basis and which have a significant effect on public or animal health are included in this group. Many of the diseases are notifiable in the Member State itself but there is no necessity for 24 hour or weekly reporting to the Commission. Eradication programmes for tuberculosis, brucellosis and Enzootic Bovine Leukosis (EBL) in cattle have continued over a long period. Brucellosis in sheep and goats is of major importance and in order to facilitate trade measures must be taken to ensure that infected herds are restricted. Proposals have been made requiring France, Greece, Italy, Spain and Portugal to produce plans for the eradication of B. melitensis in sheep and goats.

Disease surveillance and notification must be effective to ensure outbreaks of these diseases are identified at an early stage in order to prevent movement of animals out of infected herds. Movement restrictions will be applied to these herds until such time as disease clearance and freedom can be re-established. Effective policing and control of the infected herd is important to ensure animals are not traded and placed on the market anywhere within the Community. These procedures can only be implemented by the Veterinary Services of the country in which the herds are resident.

Group 3 diseases: These include endemic diseases which may be the subject of compulsory or voluntary national control programmes or a national monitoring programme. Member States may submit the programme to the Commission giving details of the disease distribution, cost benefit analysis and the geographical area in which the programme will be implemented. The various categories of animals to be included, along with details of the testing, the programme monitoring procedures and the action to be taken if a holding loses its status must be included in the submission. A method must also be established whereby animals of lower status can move into higher status herds and equally the disposal of infected animals and the re-establishment of freedom within the infected flock or herd must be detailed.

The EC examine the programmes and if they comply with the above criteria additional guarantees and safeguards for intra-Community trade will be permitted provided these do not exceed those which are implemented nationally. It is not the intention of the EC that Member States will submit a wide range of voluntary or compulsory programmes as these are not intended to introduce additional trade barriers. The EC recognition of health schemes provides a strategy whereby effort put into control programmes in Member States on an individual basis is not lost as a result of the internal market.

Groups 4 and 5 diseases: Zoonotic diseases, not covered elsewhere, are categorised within Group 4 which also includes those diseases for which special Community action is justifiable in support of local operations to eliminate pockets of infection. Eradication and control measures may be developed where appropriate. Group 5 covers fish diseases.

Contingency planning

Contingency planning provides an important operational safeguard and, in the case FMD, each Member State has to draw up a plan specifying national measures to be implemented in the event of an outbreak. The Commission has laid down the comprehensive criteria to be used in drawing up the plan which covers the requirements for plant equipment, personnel etc necessary for the rapid elimination of the disease. The wide range of measures must be covered by the plan and includes legal powers, financial provisions, national disease control centres, local disease control centres, epidemiological teams, personnel, equipment and facilities required, diagnostic laboratories, contingency plans for vaccination and training. Each Member State had to submit its FMD contingency plan to the Commission by 31 December 1991 after which it will be examined and recommendations made to ensure plans are of the

same standard in each of the Member States. Contingency planning will ultimately be extended to other exotic diseases to ensure that there is a uniform approach by the Veterinary Services throughout the Community.

VETERINARY CONTROLS

Veterinary Services

The realisation of the internal market will be dependent on the Veterinary Services in each Member State having the capability for effective control of disease and provision of the necessary veterinary checks and certificates. A high degree of mutual trust needs to be established to ensure that each Member State has confidence that the Veterinary Services throughout the Community achieve and consistently maintain the required standards. The importance of the Veterinary Services has been recognised by the Community and funds are available to improve the efficiency of veterinary inspection and programmes for the exchange of officials in a co-ordinated manner between Veterinary Services are underway. Community Reference Laboratories have already been established to give guidance and assistance to Veterinary Services. A further priority is the provision of regular training for field veterinary staff to ensure they have the necessary expertise to diagnose and control exotic disease.

In order to assist Veterinary Services within the Member States and to ensure that the necessary infrastructures are in place to deal with the free market, an evaluation of organisational structure and function has been underway by a team of consultants employed by the EC. The study has concentrated on high priority functions within animal health, public health and animal welfare and the consultant's report will be presented to the EC for each country. The animal health disease notification system, emergency procedures, health certification and the control of imports from third countries have a high priority for review by the consultants. It is hoped by these measures that confidence in the ability of the Veterinary Services throughout the Community to control disease and provide the necessary certification will be raised and contribute to the success of the free internal market.

Veterinary expenditure

The use of resources to control disease within the Community cannot be an open-ended commitment and funds need to be used in an economic and effective manner. During 1990 it was estimated that over 70 million European Currency Units were allocated to disease control and eradication programmes.

Expenditure in the veterinary field was the subject of a Council Decision in 1990 (90/424/EEC) when it was accepted that the adoption of measures to establish the internal market involved a financial commitment by the EC. This included the eradication of existing diseases and the introduction of emergency measures to deal with 12 diseases including Rinderpest, Rift Valley Fever etc if they should occur in a Member State. The financial commitment for emergency measures includes slaughter,

cleaning and disinfection, establishment of protection zones, measures to control spread and compensation to livestock farmers provided the control measures are applied immediately.

A financial contribution from the Community is also available for the eradication of FMD provided the Member States comply with the Council Directive on disease control. Financial contributions are currently made towards eradication of diseases which include CSF, ASF, CBPP and IHN. In addition, funding by the Community is available in the case of bovine brucellosis, tuberculosis and enzootic bovine leukosis and for the eradication of brucellosis in sheep and goats. Community funding could also be available for other diseases listed in an Annex to the Decision. However, funds are not unlimited and priority must be given to ensure that resources are available to deal with emergencies and control of Group 1 diseases in particular.

Veterinary checks

Existing trade provisions include the implementation of national rules at the point of entry with inspection of animals and, where necessary, quarantine for a specified period of time. Post-import isolation and testing is also permitted especially following the importation of animals from third countries. The eventual elimination of veterinary checks at frontiers for certain live animals and non-human food animal products will be essential to enable the free market to develop. In order to complete the internal market, four Council Directives laying down the principles for veterinary checks have been enacted. Two of these concern the veterinary checks applicable to intra-Community trade in live animals and livestock products, whilst two concern the organisation of veterinary checks on animals and animal products entering the Community from third countries. The main provision in these Directives requires checks at the place of production and random non-discriminatory checks at the place of destination which may be farm, market, abattoir or other places. Additional provisions provide for action to be taken by the Member State if there is a suspected irregularity in transit or at a port. Dealers must be registered and keep records and 24 hours advance notice of arrival must be given to the Member State of destination. Electronic messages, using a system known as ANIMO, will be despatched from the local veterinary unit responsible for the holding of origin to the local veterinary unit in the country and area of destination. The messages will be despatched on the same day as the health certificate is signed which will enable random, non-discriminatory checks to be made at the destination.

During a transitional period the Directives permit the continuation of documentary checks at any point during transport in order to check compliance with EC or in their absence national rules. At present the Directive concerning veterinary and zootechnical checks applicable to intra-Community trade in certain live animals and products requires that all animals covered by the Directive when entering intra-Community trade, not just those for breeding and production, must be accompanied by a health certificate issued by the veterinary authorities. Animals moving within a Member State do not as yet need to be accompanied by a movement document.

A Directive on animal products imported into the Community from third countries requires all consignments of certain specified animal and fishery products to be subject to documentary and identity checks at the point of entry into Community territory. These checks must be carried out at approved border inspection posts and, when necessary, physical checks of the products may take place on a random sampling basis as detailed in the Directive. Safeguard measures are also incorporated into the controls whereby action can be taken if diseases are reported from the third country.

Veterinary checks on live animals entering the Community from third countries are also to be covered by a specific Directive which lays down that all live animals, excluding pets, entering the Community territory must be taken to an approved border inspection post or, where appropriate, an approved quarantine station for full documentary, identity and physical checks. The border inspection posts need to meet certain prescribed criteria regarding location, staffing, structure, facilities and the need to be approved. The Directive also spells out the action to be taken, reports to be made and the method of dealing with irregularities and animals with inadequate certification.

The common date of implementation for these Directives is 1 July 1992 although both the third country Directives provide for a 3 year transitional period.

A computerised system to link veterinary authorities with a view to facilitating the exchange of information between the competent authorities when a health certificate or document accompanies the animals or products of animal origin will be needed for intra-Community movements and for movements from third countries. The system, known as ANIMO, is being developed with a view to introduction on 1 July 1992 and will involve the transmission of information from the Veterinary Unit at the point of origin to the Veterinary Unit at the place of destination. A similar system known as SHIFT will be introduced at border inspection posts in order to check animals or products imported from third countries and notify the Member State of destination that they have been imported into the Community.

CONCLUSIONS

The purpose of this paper has been to review disease control programmes within Europe. Much has been achieved since The Single European Act was signed in 1986. Rules have been established for the control of diseases such as FMD and CSF and discussions continue to establish single Community rules for the control of Newcastle Disease and Avian Influenza. Council Directives on the animal health conditions governing intra-Community trade and imports from third countries have been introduced for poultry and hatching eggs, sheep and goats, bovine embryos and bovine semen. Discussions are currently taking place on the animal health conditions governing the intra-Community trade in a wide range of species which have not yet been included in other specific Directives.

Four Council Directives concerning veterinary checks applicable to intra-Community and third country trade provide a basis whereby veterinary checks will be carried out at the place of despatch thereby superseding checks currently carried out at frontiers. It is recognised that protective measures, in order to be effective, must be established by the Member State of despatch but there must be rules and regulations to ensure that the EC can act speedily and that on-the-spot visits and checks can be made.

It is also important that resources are available, both to fund the eradication and control programmes and to ensure that the Veterinary Services in each of the Member States have the correct infrastructure and training necessary to deal with disease and provide veterinary certification.

A great deal has been achieved since 1986 and, against an overall Community aim of achieving free movement of animals and their products throughout the Community, it has been necessary to discuss and agree conditions which would ensure that risks, to either animal or public health, would be minimised.

UK legislation implementing outstanding Directives will be made over the coming months and will be the subject of a major communication exercise between the Agriculture Departments and the Industry.

The practising veterinary surgeon, as the farmer's first point of contact, remains a vital part of any surveillance system. This role remains a vital one within the Single Market and it will be important to take account of all factors when considering differential diagnosis.

CURRENT ATTEMPTS TO IMPROVE WELFARE AND POSSIBLE LINKS WITH FARM ANIMAL DISEASE

D.M. Broom*

Much of the legislation whose aim is to improve the welfare of animals includes reference to the necessity to reduce disease incidence. This is logical since the welfare of diseased animals is clearly not as good as that of those which are not diseased and indeed welfare is very poor if clinical disease is severe (Broom 1988a, b, Fraser and Broom 1990). Hence in this way, general improvement and disease reduction change in parallel.

If changes are made in animal husbandry methods and in housing conditions which result in better welfare they will sometimes affect the functioning of the immune system. A variety of difficult conditions result in immunosuppression (Kelley 1985) and it is certain that there are far more examples of this than have so far been demonstrated. Housing conditions in which animals live for a long time and frequent aggression by others can both lead to impaired immune system functioning and it is likely that such effects are widespread. If disease challenge occurs then serious clinical effects are more likely in an immunosuppressed individual and as a consequence, disease spread is also more likely.

One change in the housing of farm animals which may have epidemiological consequences is the housing of animals in social groups rather than in individual crates, stalls or pens. The fact that our farm animals are social and show abnormalities of behaviour and physiology when housed for a long period in conditions which do not allow social interaction. Another factor has been the inability of animals in small crates or stalls to groom themselves adequately or obtain sufficient exercise. Once crates and stalls are large enough to allow such freedom of movement, it is cheaper to keep the animals in groups.

The consequence of abolishing the use of small crates for veal calves in the United Kingdom are not yet fully known. Young calves have to obtain and absorb enough colostrum and absorption is known to be affected by the presence of the mother. Absorption may be improved by the presence of other calves but in general this will not be of great importance where calves are left with their mothers for the first 24 hours of life. Calves are susceptible to respiratory and gastrointestinal disorders and some of these are transmitted by close contact. However it has been demonstrated by the work of Webster and others that both respiratory and gastrointestinal infections are very rapidly transmitted through buildings containing only individually housed animals. There is a considerable prejudice amongst farmers and some veterinary surgeons in favour of individual

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penning of calves during the first few weeks of life. Some even advocate the extreme isolation caused by the use of solid-walled pens. There may sometimes be an advantage of this practice in reducing disease transmission but that advantage must be set against the disadvantage that all calves are seriously disturbed by such housing and are probably immunosuppressed to a degree which is of considerable importance in relation to disease. There is no doubt that calves can be reared on straw in a way which does not result in high morbidity. The rearing of calves on slats at a high stocking density can lead to a higher morbidity than crate housing.

The pig industry in the United Kingdom has moved towards a minimal disease situation on most units. As a consequence, diseases are much better controlled than they used to be. Hence a change such as the move from stalls and tethers to group-housing is unlikely to result in increased disease transmission within herds. Indeed the better welfare associated with greater freedom of movement and more opportunity to engage in social interactions probably results in higher levels of immunocompetence. Certain kinds of morbidity in sows are reduced if there is more freedom of movement, as demonstrated in a large survey many years ago by Bäckström (1973). Some of this morbidity is associated with more leg problems and more farrowing difficulties if the sows are confined. Another well studied effect is that on urinary tract disorders of sows Tillon and Madec (1984) demonstrated that prolonged lying, which is characteristically shown by inactive unresponsive confined sows, increases the likelihood of urinary tract disorders. The change to group-housing should reduce most of these problems but some animals in groups are the subjects of frequent attacks. If these, or their aggressors, are not removed they may be immunosuppressed and more prone to disease.

The housing of the laying hen is the subject of much discussion at present. Most alternatives to the battery cage include attempts to separate the hens from their droppings. For example the Dutch Tiered Wire Floor system has some droppings in the litter area but most of the droppings are removed by conveyor belts under the wire floors. Current trials do not suggest that disease incidence is any higher in this system, or in any of the three widely used Swiss systems, than in battery houses. Free range hens, however, can be particularly susceptible to disease outbreaks unless they are moved to fresh ground every six months. The dangers of infectious disease must always be considered.

A variety of other attempts to improve welfare have possible consequences for disease spread. If dairy cow housing is improved so that the animals find the conditions more comfortable and are less likely to be injured in them, the incidences of mastitis and lameness should drop. If handling procedures and conditions during transport are improved then disease incidence should drop.

The general conclusions about the inter-relationships between welfare improvement attempts and disease are: firstly that disease is an aspect of poor welfare and many actions will be of benefit in both respects. Secondly, that the possible trade off between reduced immunosuppression and increased disease transmission risk should be carefully considered in all attempts to improve welfare. Thirdly, that there are differences between production or system related diseases and dangerous infectious diseases. Whilst we have quite a lot of information about the former, the latter should also be borne in mind when developing new systems for housing and managing animals. Our overall aim should be to improve welfare in total and we should always include consideration of the effects on individuals of any disease which they might contract.

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RESIDUES : SAMPLE SELECTION

W. J. McCAUGHEY *

Consumers require assurance that their food does not contain drug residues. However, a wide range of these are used to prevent or to control infections and to promote growth in farm produced food animals. The aim of residue testing programmes is to identify foods in which violative concentrations of unwanted drugs, or their metabolites, remain at slaughter so that these can be prevented from entering the food chain.

An absolute guarantee of freedom from even one single drug residue can only be achieved through exhaustive testing of all animals or carcases. Even if this level of testing were practically possible it would be financially crippling for the industry. The compromise normally adopted is a frequency of testing which will provide an acceptable degree of assurance for the consumer or customer. A variety of factors, not all of which are immediately obvious need to be considered before residue testing programmes are initiated. A number of these can be illustrated by examples taken from the practical experiences or residue control in Northern Ireland. This paper outlines some aspects of sampling strategies, sample numbers and sample types and discusses their advance for quality assurance.

BACKGROUND TO THE PROGRAMMES IN NORTHERN IRELAND

All meat and poultry plants in Northern Ireland are licensed to operate by the Department of Agriculture. The annual appropriate outputs are shown in Table 1.

TABLE 1. Annual meat outputs from Northern Ireland.

Species	Quantity
Cattle	500,000 carcases
Sheep	1,400,000 carcases
Pigs	1,100,000 carcases
Poultrymeat	72,000 tonnes
Shellfish	2,000 tonnes

Meat inspection services are provided either by the Veterinary Service of that Department or by the Environmental Health Service of the Department for the Environment. These services are staffed by trained meat inspectors who are responsible for the meat inspection and for national plan sampling and have powers to detain and condemn carcases. In comparison with Great

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Britain there are relatively few plants (12 cattle, 4 sheep, 6 pigs and 7 poultry). Supporting laboratory services are provided by the Veterinary Sciences Division of DANI for both meat inpsection and national surveys.

National plan testing is based on random sampling. The number of samples required to fulfil UK obligations under EC Directive 86/469 are determined annually and the proportion allocated to Northern Ireland are collected from each plant in proportion to the previous year's throughput. Meat inspection sampling is determined by the inspectors and is determined by their judgement of individual animals and carcases. As such the numbers in any period can only be estimated from previous experience. The number of samples collected for National Plan and meat inspection analysis in 1990 are summarised in Table 2.

TABLE 2. Annual sampling for residue testing.

Analyte Group	Number of Samples
Antibiotics	8,500
Sulphonamides	7,000
Hormones	4,000
Feedingstuffs	750
Shellfish toxins	75
Algal toxins	15

SAMPLING STRATEGIES

Internationally acceptable control programmes usually require collection of samples from randomly selected animals presented for slaughter. The number of samples taken to provide an assurance with a selected degree of confidence can be taken calculated (Table 3).

TABLE 3. Number of samples required to detect at least one violation given a known violation rate.

Violation incidence	Minimum number of samples required to confirm that violations occur		
	95%	95%	95%
35	6	7	11
30	7	9	13
25	9	11	17
20	11	14	21
15	15	19	29
10	22	29	44
5	45	59	90
1	230	299	459
0.5	460	598	919
0.1	2302	2995	4603

This table illustrates the relationship between sample size and ability to detect violations. However, there are several specific criteria that need to be met before these conclusions can be drawn.

Firstly the population has to be homogeneous. It is difficult to argue that any population of food animals can be so described. In Northern Ireland the pig industry may be the most homogeneous but the beef industry is becoming organised into ever more specialised units and sheep producers are actively seeking new market niches for expansion. Even the broiler industry can be fragmented both by production methods (intensive or free range) and by final carcase weight.

Secondly the method of selection needs to ensure that individual bias does not influence 'on site' identification of carcases for examination. When programmes were initially introduced selections were under individual plant control. The results suggested that two diverse criteria could be adopted. In one, carcases would be selected when the meat inspection team were suspicious of quality and wished to add to their knowledge on possible abuses. Under this system the abuse rate was overestimated. In the second, suspicious carcases would be avoided as the positive could attract unwelcome attention to the plant. This selection underestimated violations. In view of the few positive carcases which enter the chain, analysis over a considerable period would be required to detect these aberrations and to relate the results to sampling bias.

In Northern Ireland the National Plan sampling strategy avoids bias and is based on a schedule which approaches truly random selection. At the beginning of each year the numbers of samples to be collected are allocated to each plant in proportion to the previous year's throughput. (The system has a proportion of extra samples incorporated to ensure that adequate numbers are taken to compensate for errors). For each sample an animal type, date and time is specified and the inspection service is instructed to sample the next suitable animal presented after that specific time. This mechanism compensates for uneven throughputs, for plant stoppages and for variations in animal types presented at each plant. Regular checking of samples received at the laboratory is required to ensure that major plant changes are compensated at an early stage.

Random selection of samples for testing provides information on the frequency with which violations can be expected to occur and is therefore favoured for National Plans and many Food surveys.

TABLE 4. Probability of failing to detect abuse for a given sampling rate.

Violation Incidence	Numbers of animals examined						
	5	10	25	50	100	250	500
1%	0.951	0.904	0.778	0.605	0.366	0.081	0.007
2%	0.904	0.817	0.603	0.364	0.133	0.006	
4%	0.815	0.665	0.360	0.130	0.017		
8%	0.659	0.434	0.124	0.015			
16%	0.418	0.175	0.013				
32%	0.145	0.021					
50%	0.031	0.001					

However because a large majority of samples are expected to prove negative it is not an efficient means of detecting or of deterring further abuse. Reduced numbers of samples introduces a risk of collecting inadequate information and failing to detect abuses (Table 4).

Selective targeted sampling can reduce the risk of failing to detect abuse by concentrating attention on animals which are identified as having an above average risk of containing an unwanted residue. Selection can be based on several criteria. The evidence used to indicate potential risks at Northern Ireland plants is obtained by observation, during ante-mortem inspection eg above average conformation for breed type, sex or age; during regular meat inspection eg injection sites; from previous records of offences eg previous positive carcases; or from other local information.

Ante-mortem inspections identify animals as potentially antibiotic positive due to observations such as lameness, mastitis, or other clinically detectable abnormality. Unusual behaviour such as excessive riding or aggression has been used to select for hormonal growth promoter examinations. Cattle which show excessive muscular development for breed and sex type are selected for beta-agonist testing.

Regular meat inspection is at the forefront of selections for injectable drug use as sites can remain detectable for some time after administration. Clinically abnormal animals can be followed at all stages in the plant to detect injection sites or, if none is detected, to ensure that samples are taken to confirm freedom from orally administered therapeutics. During 1990-1 there was close correlation between the drug use admitted by presenters (Figure 1) and the residues detected in laboratory tests. Although withholding times have been specified for these antibiotics the tissue into which they are injected is important in determining the clearance rate. In a recent laboratory experiment ampicillin injections into the necks which lodged between the ligamentum nuchae were found to be almost unchanged in calves killed 6 weeks later. This finding is considered unusual but it highlights the need for care.

Growth promoting hormones alter the conformation and behaviour of finished cattle. Hormone implants are banned for use in EC countries and since the ban became effective positive carcases are declared unfit for human consumption. Implants can be identified in carcases for lengthy periods after insertion. The 1990-91 results (Fig. 4) show that these are being eliminated from the system.

After growth promoting hormone implants were banned the beta-agonist, clenbuterol, was used by a number of producers as an illegal feed additive to achieve the carcase conformation required for some markets. Testing for residues of clenbuterol began in 1990 and was increased in 1991, accompanied by condemnation of the carcases. The results in 1991 show that this abuse has been controlled.

Drugs which are incorporated in feed do not leave a detectable mark in the carcase. The most commonly occurring antimicrobial residues in pigs, sulphadimidine and chlortetracycline, are normally administered in feed. Residues of these have been identified in most pig producing areas. A specific programme has to be set up in Northern Ireland to detect and to control the use of such drugs. Drugs incorporated in feed are usually applied to groups of animals hence testing programmes can be based on the selection of single animals to representative batches without reducing the effectiveness of detection. Positive results can then be used to initiate

Figure 1. Antibiotics Used in Cattle Preslaughter 1990-1

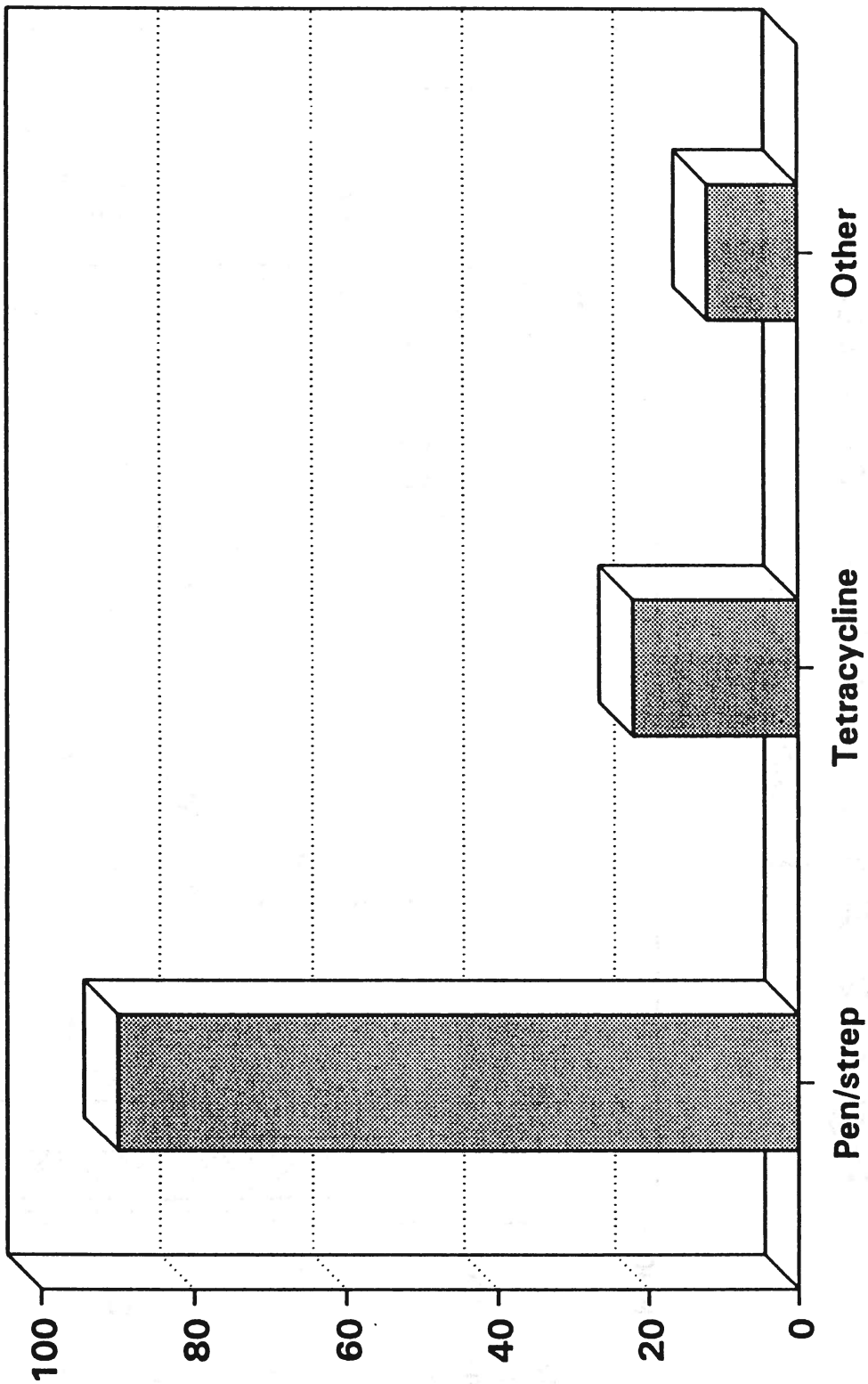


Figure 2. Antibiotic Tests on Cattle 1988 - 1991

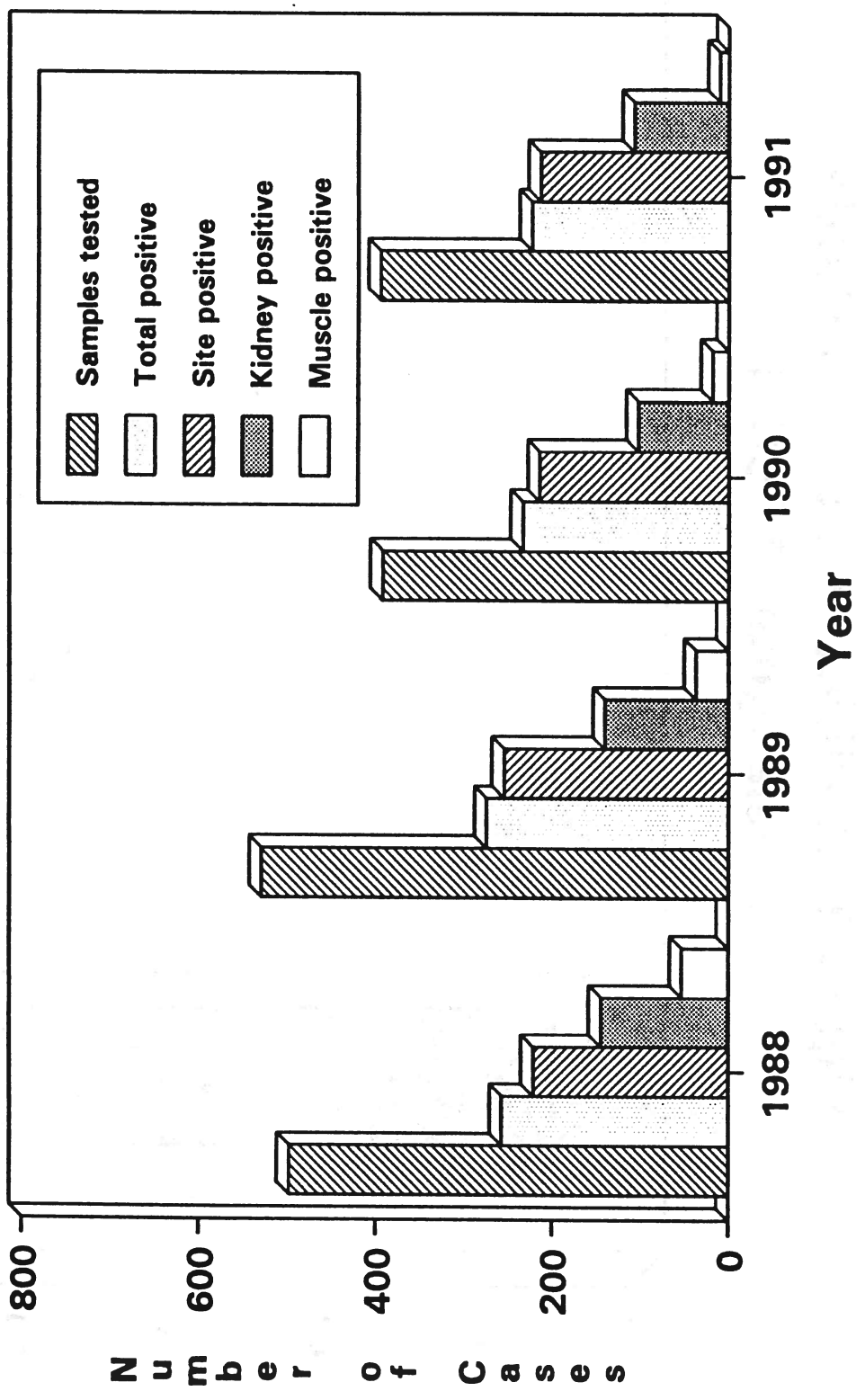


Figure 3. Pig Testing Scheme Sulphadimidine ELISA Results

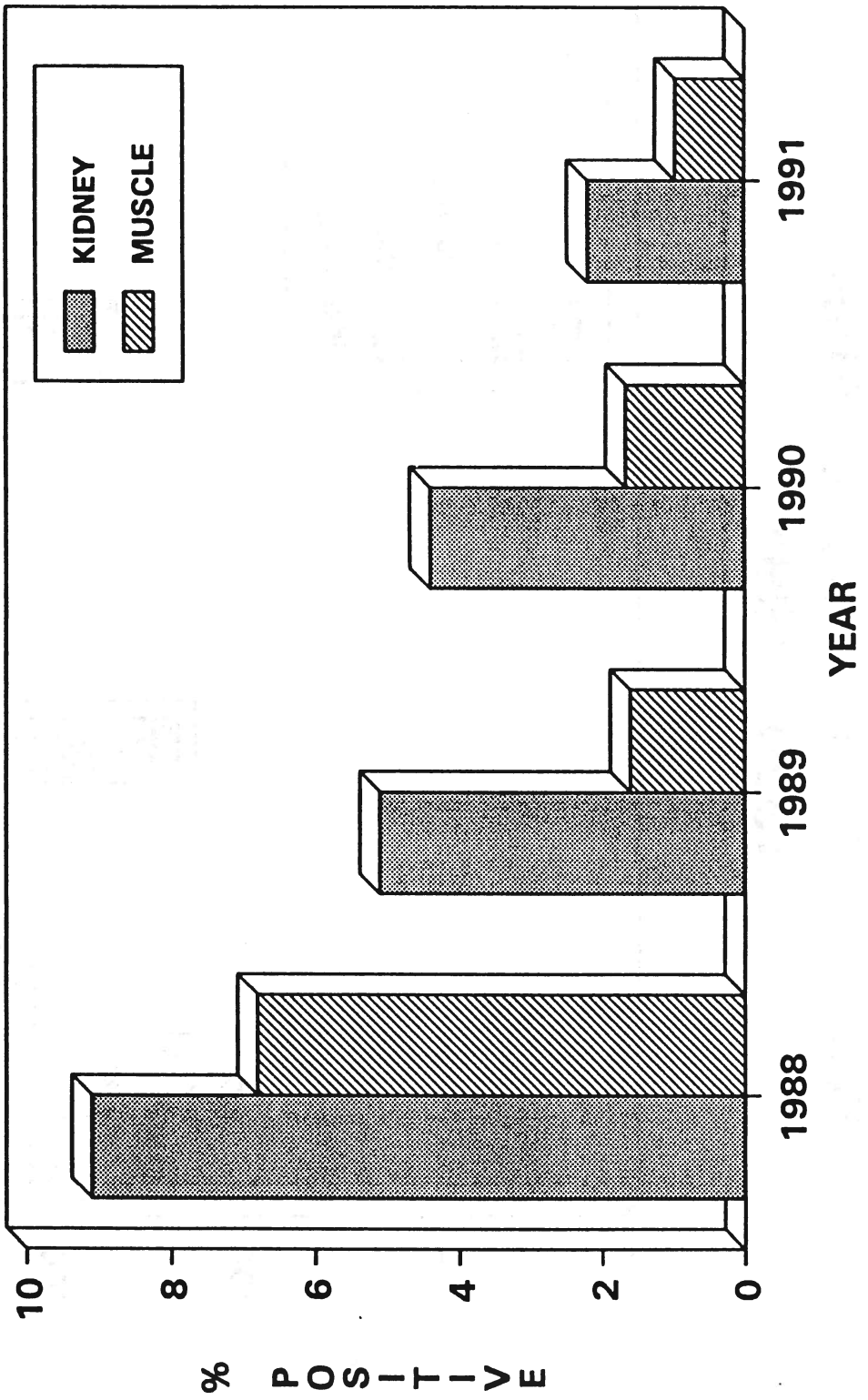
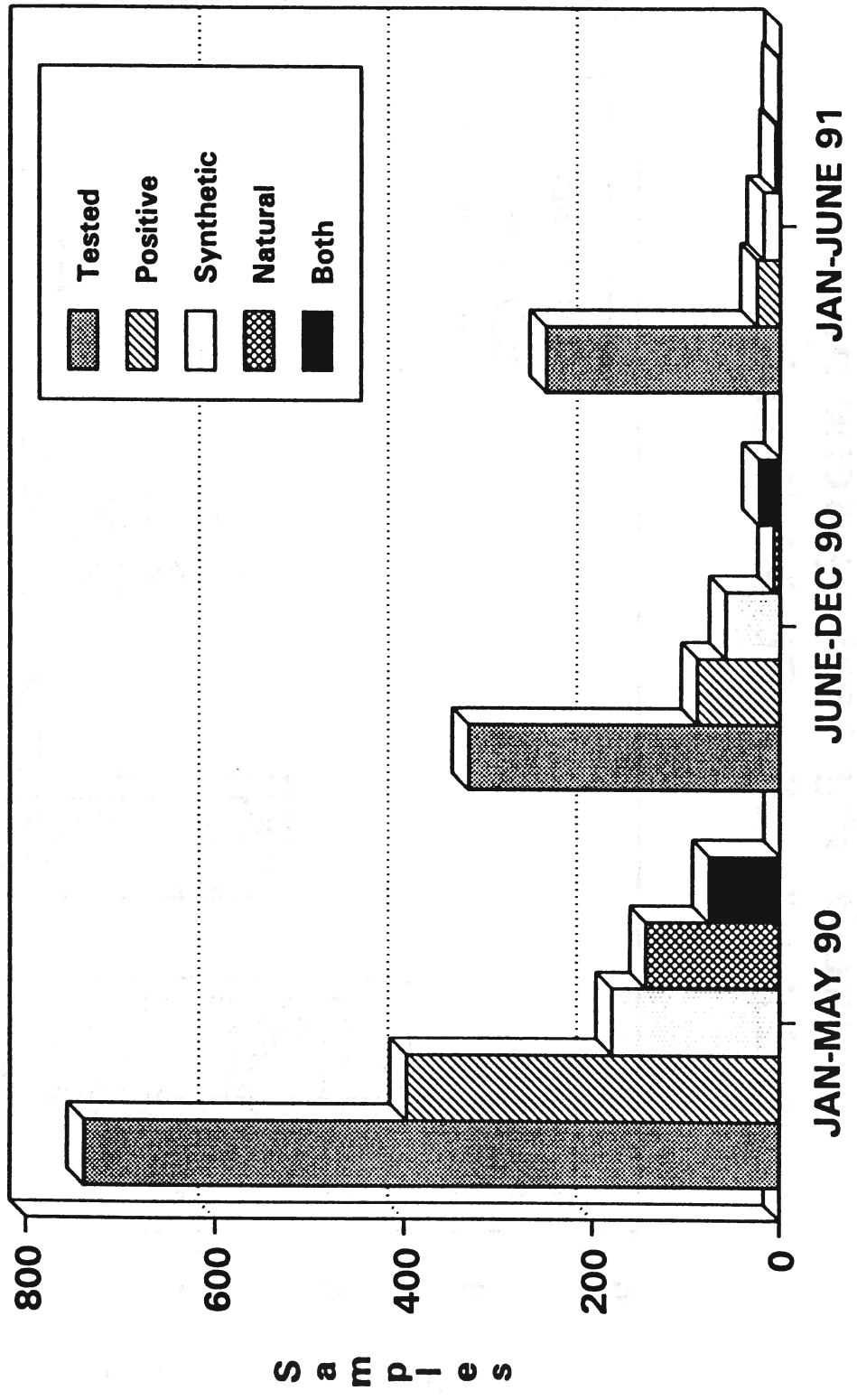


Figure 4. Suspect Implant Sites 1990 - 1991



more intensive herd testing. This testing programme results in effective use of resources to identify producers who are abusing the system. The programme to control antimicrobial residues in pigmeat which has resulted in a reduction in frequency of sulphadimidine violations (Figure 3).

In summary random sampling provides information on the population but selective sampling can improve the effectiveness and efficiency of laboratory testing for residues. To minimise risks of failure random sampling requires large numbers of tests and the basis of the selective sample demands selection must be closely linked to use of the drug whose residues are being sought.

SAMPLE TYPE

There is a correlation between the sophistication and cost of methods to detect and identify drug residues in food. Screening (primary) methods are relative simple to perform use rapid analysis and offer quick selection of potentially positive samples. Those currently in use include microbial inhibition (Bogaerts and Wolf, 1980; Lott, Smither and Vaughan, 1985), immunoassays and chromatography of simple extracts (Heitzman, 1984). As most samples collected randomly in residue control programmes do not contain drug residues prior screening selects only those which require detailed analyses resulting in improved cost effectiveness of the system. Confirmatory (reference) methods are required to be based on an independant quantitative analytical method. Techniques which include high resolution mass spectrometry and thus provide information on the chemical structure of the residue are preferred. These are normally expensive in equipment cost, time and labour.

Recent residue legislation extends the examinations of animals, meat and meat products for the presence of residues and provide powers for action when residues of prohibited or unlicensed substances or concentrations of authorised substances exceeding the maximum residue limit is identified. There are two main implications for laboratories involved in residue analysis in the this legislation.

Techniques will have to be rapidly performed to support meat inspection when carcases are thought to contain more than the MRL. Survey testing as carried out at present involves collection of samples from selected carcases followed by testing which can be deferred until sufficient have been accumulated for economical batch processing. Technology which is suitable for this procedure may not be appropriate when rapid turnaround times assume primary importance. The adoption of MRL's requires that all residues of licensed drugs must be quantitated accurately within the same time limits. Extension of residue analyses to live animals reduces the range of tissues which can be made available for testing and will require an extension of the validation procedures to include those samples which can be collected from live animals. In the case of licensed products producers will require more detailed information on withholding times to ensure that penalties are not incurred through presenting animals to soon after therapy. In view of the variations which can occur in farm situations it is likely that this information will be more readily acquired through ongoing residue analyses than from experimental studies.

The technology used in analysis and the turnaround times required both influence the selection of tissues included in samples taken for analyses. Body fluids are preferred as they are more homogeneous than tissues and frequently need simpler preparation and extraction procedures.

However the pharmacokinetic properties of many drugs can require tests to be performed on other tissues and it is in the interest of consumers that edible tissues are examined regularly particularly when MRL's are established. These considerations are important when decisions are taken on the samples to be submitted for laboratory testing. Simplification of sampling procedures avoids risks of confusion and of errors in submissions. In the Northern Ireland programmes random sampling seeks to provide complete sets of tissues for each carcase. A set includes blood, urine, bile faeces, liver, kidney and muscle. Although tests are carried out on subsets of these the remainder are available for technique development and 'ad hoc' surveys of drugs not yet included in official programmes. Samples taken from meat inspection carcases at present include injection sites, kidney and muscle. The following examples demonstrate how these sampling procedures are applied in Northern Ireland.

Antibiotics are derived from several structurely very different groups of chemical substances. Their common characteristic is antimicrobial activity. The most commonly used screening test for antibiotics is the four plate microbial inhibition test (Bogaerts and Wolf, 1980) which exploits residual antimicrobial activity in tissues of treated animals. This test is cheap, rapid and will detect multiple residues. However it not effective for the detection of sulphonamides, chloramphenicol or nitrofurans. The results of field investigations show that this test will detect the antibiotics most commonly used in adult cattle (Figure 1). This test has been applied in the support of meat inspection for several years and there has been a steady decline in the frequency of positive samples (Figure 2). This decline has affected not only the number of positive tests but more importantly the frequency of positive muscle. In this case the availablity of several tissues adds to the value of the laboratory information which can be made available to the meat inspection service as a guide to suitable judgements. The results of the test can give a preliminary indication of the antibiotic involved or this can be obtained, particularly when a site is available for testing, by high voltage electrophoresis.

As described above residues of sulphadimidine have been recognised as a problem in most pig producing areas. An MRL has been established at 0.1 ppm in edible tissue. The four plate test is not suitable for the detection of this residue nor could it be expected to give quantitative information. In Northern Ireland an ELISA technique was developed to screen large numbers of pig carcases and to introduce control measures. Residue concentrations above the MRL are confirmed by an independant high performance liquid chromatography procedure and a gas chromatography mass spectrometry technique has been developed. A continuous rolling survey was established to detect violations by collecting urine, kidney and muscle from animals at plants. Screening initially examines unextracted urine to select those carcases which require further testing. Kidney and muscle from positive urine carcases are examined by the ELISA and confirmed by an HPLC procedure. Producers presenting animals containing concentrations above the MRL in edible tissue are penalised by condemnation of the carcase. Since its introduction this programme has achieved a steady decline in the number of violations (Figure 3). During the most recent round of testing the frequency of violations has fallen further. The system of urine screening adopted for this programme has reduced the laboratory material and labour inputs by up to 40% thus increasing the cost-effectiveness.

The ban on the use of growth promoting hormone implants has presented several unique problems in residue testing. The concentration of each hormone in body fluids is low even shortly after implantation and falls

progressively rapidly reaching non detectable levels. However a residual quantity of he implant remains at the site and retains detectable quantities of the hormone for an extended period, possibly for the lifetime of the animal. These may be detected at slaughter if they are in areas which are subject to examination. To avoid detection some producers have attempted to place implants in areas which are not normally inspected. This abuse of some hormones, for example trenbolone, can be detected by the appropriate choice of sample. The drug enters the enterohepatic cycle and remains in detectable concentrations in bile for considerable periods after becoming non-detectable in body fluids. As this use is illegal detection and confirmation in bile is sufficient evidence for regulatory control. The decline in abuse is demonstrated in Figure 4. In live animals, which are tested on farms following each identified violation, faeces has been shown to be the best sample to examine.

After the ban on hormonal growth promoters attempts were made to obtain similiar benefits of better grading and carcase conformation using the beta-agonist clenbuterol. This drug provides an example of the care which needs to be taken in selecting target tissues for testing. When animals are fed growth promoting concentrations the residue accumulates in various tissues and is excreted in urine. During withdrawal the urine concentration declines rapidly and selective depletion of tissues occurs. A variety of tissues taken from experimental and suspect slaughter animals were exaimed before liver was selected as the most appropriate for residue control. During the examination of kidney tissues the concentration was shown to be lower than that in associated liver and lack of homogeneity was demonstrated, possibly as a result of cortical and medullary differences. This information was not available at the initiation of the testing programme but when applied to animals on presentation for slaughter followed by condemnation of positive carcases was followed by a rapid decline in abuse.

SUMMARY

This paper has sought to address the importance of selecting adequate numbers of animals for sampling to provide the information required to assure consumers. The potential for improving cost-effectiveness by selecting specific segments of the industry for concentrated effort has been outlined with particular emphasis on the interaction of meat inspection and residue analysis. Some of the opportunities which exist for improving the benefits of laboratory technology by strategic sample selection have been discussed. The beneficial results achieved by the application of these principles in producing wholesome food through a coordinated meat inspection service are demonstrated by several examples.

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PORCINE REPRODUCTIVE AND RESPIRATORY SYNDROME (BLUE EARED PIG DISEASE): SOME ASPECTS OF ITS EPIDEMIOLOGY

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Crucial to the containment, control or eradication of any disease condition, whether infectious or not, is an understanding of its epidemiology. It is often necessary, however, to initiate some form of control long before the complete epidemiological picture has been fully elucidated.

In November 1990 a new pig disease, now known as porcine reproductive and respiratory syndrome (PRRS), was reported in Germany in North Rhine Westphalia. Several cases occurred in Spain in January 1991. By mid-January 1991 pig herds in the Netherlands were affected and the disease had reached Belgium by March.

By the time our Ministry received the first report on 16 May 1991 of symptoms suggestive of PRRS in a large breeding herd in South Humberside it was known that the disease was infectious, probably caused by a single viral agent, and that the agent was disseminated by pig movements and almost certainly by the wind. The Netherlands reported that their first case had occurred 20Km from the German border and suggested that meteorological conditions early in 1991, when there had been low temperatures, high humidity and moderate wind speed, would have been such as to favour the airborne spread of a viral agent. The prevailing wind direction was

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consistent with the observed development of the epidemic towards the west and south west; but there was a problem in interpreting the case data in that, as later proved to be the case in our own investigations, it was often difficult to determine, with any degree of accuracy, the date of introduction of the agent or even the precise date on which the first clinical manifestation of the disease had occurred in a particular herd. The true temporal pattern of the disease spread was, therefore, difficult to define. The Spanish cases in Huesca were attributable to the movement of store pigs from Germany to two finishing units with some subsequent spread to nearby breeding herds.

On 25 April 1991 the Commission of the European Communities adopted a decision (91/237/EEC) which replaced an earlier, less detailed, decision of 1st March 1991 (91/109/EEC) and put in place measures to limit the spread within the Community of the new pig disease. In the decision of 25 April an infected holding was defined as one on which "unusual numbers of abortions or premature farrowings in sows or gilts and deaths and weakness in young piglets, not attributable to known diseases, have been observed within the last eight weeks".

The Dutch authorities, responding to the vagueness of that definition, evolved more precise criteria for the confirmation of the disease. These were any 2 of the following within a 14 day period:

abortion and/or premature farrowing exceeding 8%;

stillbirth exceeding 20%;

mortality of piglets in the first week of life exceeding 25%.

PHASE I OF CONTROL

As far as our own suspected case was concerned several answers were urgently required. The urgency grew as more cases were reported.

Was this PRRS?

If not, what was it?

If it was, how had it travelled from continental Europe to Humberside?

How was it moving around within Great Britain?

In May we lacked specific legislation to deal with this problem disease and, therefore, made use of the Movement of Animals (Restrictions) Order 1990, which enables certain action to be taken to control any disease of animals, including the service of notices on suspect premises prohibiting the movement off of pigs, carcases, manure etc. Such restrictions were imposed on the suspect herds, but finished pigs were permitted to move, after clinical inspection and under licence, direct to an abattoir for immediate slaughter. The first notices under the Order were served on 21 May 1991 on two pig farms, one in South Humberside, the other in the North of the same county. This I will call Phase I of our control programme.

The powers given by the Order were deficient in two respects. They did not allow the imposition of infected area restrictions to minimise the risk of disease spread in the area surrounding a known infected unit; nor did they allow restrictions to be placed on premises on which the disease was not suspected or known to be present, but which were considered to be at risk, most significantly as a consequence of the introduction of pigs from infected herds.

PHASE II OF CONTROL

Phase II of our controls came with the introduction of the Movement of Animals (Restrictions) (Amendment) Order 1991 which came into force on 24 May 1991. The new Order took account of the first of those shortcomings and, on the following day, infected areas were declared around the two suspected farms restricting the movement of pigs within or out of the areas accept under licence. The infected areas extended at least 3Km around the suspected farms, but in practice were larger since their boundaries were defined by roads, rivers and other natural features. On 30 May a third infected area was declared in Humberside, south of the river Humber near Goole. In this instance the area extended considerably beyond a 3Km radius because of an absence of geographical features by which the area could be circumscribed.

During Phase II the movement controls on pigs in the infected areas were as follows:

a. No movement of breeding pigs off any farm was permitted.

b. Slaughter pigs were allowed to be moved under a Ministry licence from any farm direct to an abattoir.

c. Growing pigs were allowed to move from premises on which disease was not suspected, under licence, to fattening units within the county of Humberside provided

that the recipient premises had no breeding stock and that there were no neighbouring breeding units.

d. From suspected premises (those under Form A) growing pigs were allowed to move, again under licence, only to fattening units within the same or another infected area, with the same conditions of freedom from the risk of contact with breeding stock. Form A was served on the receiving premises.

On 3 June a further infected area was declared, again in Humberside, around the fifth case, the fourth case having been within the first infected area adjacent to the first reported case and, we believe, the first of our cases in which airborne spread occurred.

In the week which followed, restrictions were served on seven further suspected premises, necessitating the declaration of three further infected areas, two in North Humberside, where the infected areas were beginning to coalesce, and one much further afield on the North Yorkshire - Durham border.

Phase II of the campaign ended at this point.

Reference to infected herds and infected area restrictions implies that we were confident that the disease we were seeing was infectious. By 10 June 1991 there was compelling evidence that it was an infection, but we had by no means been certain of that during the first two weeks of our investigations.

Initial diagnostic enquiries were directed towards eliminating the range of infectious diseases which might possibly have been responsible for the symptoms reported in affected herds. These were:

Aujeszky's disease
Classical swine fever
African swine fever
Bovine virus diarrhoea
Swine influenza (H1N1 and H3N2)
Encephalomyocarditis
Porcine parvovirus
Haemagglutinating encephalomyelitis
Transmissible gastroenteritis
Porcine epidemic diarrhoea
Talfan disease
Ovine chlamydiosis
Erysipelas
Leptospirosis (a range of serovars)

Paired sera were tested where appropriate. The results did not indicate that any of these diseases were implicated. (Paton et al 1991).

In addition feed samples from affected farms were examined for the presence of mycotoxins or other contaminants and an intensive epidemiological enquiry was instituted to find features common to all the reported cases. The early cases did have a common source of sow feed but, as the epidemic developed, this proved to be of no significance.

What was revealed from the movement records of the suspect herds was that six of the first ten cases had had deliveries of breeding gilts from the same source in Humberside. The investigation of that breeding herd gave a very early indication of one of the most significant problems we were likely to have in the control of PRRS. The pigs on the unit and the herd's breeding records were inspected in detail twice, in late May and early June and, although it was clear that the herd was not normal, to the extent that the sale of breeding stock had been voluntarily suspended from 21 May, there was insufficient clinical evidence to say with any degree of certainty that the problem was PRRS. The strong epidemiological connection with other known cases was, however, enough to justify the imposition of restrictions on the unit pending confirmation by serological testing.

PHASE III OF CONTROL

On 13 June 1991 there was a dramatic start to Phase III of PRRS control. On that day the new Blue Eared Pig Disease Order 1991 was made and came into force. The disease was confirmed as PRRS, on the basis of serological tests carried out at the Lelystad Institute in the Netherlands, including positive results from the primary breeding herd case. And our thirteenth suspect case was reported.

By confirming the disease as PRRS the controls imposed on Member States by Commission Decision 91/237/EEC came into effect. That decision required hygiene measures to be taken on the affected holdings and prohibited the movement of breeding pigs from infected to non-infected holdings. The other provisions related to trade in pigs between Member States.

The restrictions we have had on the movement of pigs within Great Britain from infected herds, infected areas and herds considered to be at risk from PRRS have at all times, but to varying degrees, gone beyond what was required by Commission Decision 91/237/EEC.

The new Blue Eared Pig Disease Order, made under the Animal Health Act 1981, made the disease legally notifiable.

It required a farm to be declared an infected place if there was evidence that the disease was present in the herd or had been present in the preceding 56 days. It required a veterinary enquiry to be carried out to ascertain whether or not the disease was present and allowed the collection of samples. It allowed, for the first time, movement restrictions to be imposed on herds believed to be at risk from the spread of the disease, in particular if a pig had been exposed to the infection within the previous 56 days. It allowed notices to be served requiring cleansing and disinfection of suspected or known infected premises. And it allowed the declaration by the Minister of infected areas.

Under the new Order the existing restrictions on infected premises and within infected areas were revoked and immediately replaced by new similar restrictions. The main difference was that a new enlarged infected area was declared covering the entire county of Humberside, in which the main focus of infection was located and where there was already evidence of local airborne spread. The area extended beyond Humberside into portions of the neighbouring counties of North Yorkshire, South Yorkshire, Nottinghamshire and Lincolnshire and included all the earlier seven infected areas apart from the single one on the Durham - North Yorkshire border where the density of pig herds is low. Humberside, on the other hand, has the most dense and intensive pig population in Britain and it was considered essential, if possible, to confine the problem within that area. In declaring so large an infected area with its boundaries at least 30Km from the nearest infected farm account was taken of the suggestion from the Netherlands that the agent might be carried by the wind over distances up to, and perhaps beyond, 20Km.

An incidental benefit of having so large an infected area was that weaned pigs from units within the infected area but not otherwise under specific restrictions were able to move to finishing premises also within the infected area. It had been recognised early in the epidemic that in Humberside, which has many breeding herds taking the progeny only as far as the weaner or grower stage, the interference with normal pig movements could result in overcrowding with disease and welfare problems following as a consequence. A balance had to be found in the severity of the control measures so that the restrictions imposed would not do more damage to the pig industry than the disease whose spread we were attempting to prevent.

Movement restrictions were served on premises which had received pigs from suspected or confirmed infected premises within 56 days of the start of the disease and the pigs and production records on these units were inspected by veterinary staff. Several of these were found, at that time or shortly thereafter, to have clinical disease, and by 27 June four further small infected areas had been declared in North

Yorkshire, Lincolnshire, Norfolk and the Warwickshire - Oxfordshire border, each around clinically affected premises which had received breeding stock from one or other of the two breeding herds in Humberside which had by then been confirmed by serological testing to be infected.

From each suspect herd serum samples were taken from 12 pigs at the time of the first enquiry with paired samples taken, if confirmation was not possible on the first samples, three weeks or more later. At that stage in the campaign only herds showing symptoms suggestive of the disease were sampled. Many herds were confirmed as infected on the first samples, and the percentage seroconverting was found to be high, making it unnecessary to sample more than 12 pigs, even in large breeding herds. Restrictions were served only on breeding herds unless there was a very close relationship between an infected breeding herd and a finishing unit which had received pigs during the active phase of the disease and which, therefore, was considered to be a risk to neighbouring herds.

Form D restrictions on premises which had been exposed to infection were kept in place for 56 days from the date of movement of pigs from an infected herd. Because disease tended to spread slowly from the incoming animals to pigs in the receiving herd it had proved necessary to maintain the restrictions for this eight week period, although initially 30 days had been proposed.

This "lag time" was looked at in the first eight cases associated with the movement of infected maiden gilts. The exact dates of delivery of these animals were known, as were the dates of the first appearance of clinical disease.

Table 1

Case No.	Date gilts delivered	Date disease first seen	Lag time
PDR 1	29/4	13/5	14 days
PDR 2	25/4	17/5	22 days
PDR 3	29/4	26/5	27 days
PDR 7	17/5	2/6	16 days
PDR 9	2/5	1/6	30 days
PDR 10	9/5	4/6	26 days
PDR 11	9/5	24/5	15 days
PDR 13	25/4	1/5	37 days

Virus appeared to spread slowly and to require several passages before the challenge to the sow herd was sufficient to initiate clinical disease.

PDR 10 and PDR 11 are herds located about 2Km apart. They are in the same ownership and both received consignments of gilts from the first primary case on 8 May. Integration of gilts into the breeding herd is a slower process in PDR 10 than in PDR 11, where it is almost immediate. This appears to explain the 11 day difference between the two herds in the appearance of the first clinical signs.

During this Phase III the restrictions on the movement of pigs were as follows:

Infected or suspected premises (Form A)

a. No movements off of breeding stock or growing pigs other than direct for slaughter under licence, but movements on of replacement gilts or boars was allowed.

b. Pigs for slaughter were allowed off under licence to a slaughterhouse. The licence required that the livestock vehicle was cleansed and disinfected at the slaughterhouse immediately after the delivery.

Premises at risk from infection (Form D)

Form D restrictions were served not only on premises which had been put at risk of disease by the delivery of pigs from Form A premises but also on all breeding units within 1Km of Form A premises as it was considered their proximity to the infection put them at risk from local airborne spread of the agent.

a. No movement off of breeding stock other than direct to slaughter under licence.

b. Movement of slaughter pigs direct to an abattoir under licence with the same conditions as for pigs from Form A premises.

c. Weaners and growing pigs from "geographical" Form D premises, that is from premises within 1Km of Form A premises, were allowed to move to finishing units within the same infected area provided the receiving premises had no breeding stock and there were no breeding herds adjacent to the receiving premises. The receiving premises were placed under Form D restrictions for the 56 days following the movement, which meant that they were able to move pigs only direct to slaughter under licence.

Form D premises outside the infected areas which were weaner breeders were, of course, at a disadvantage as they were unable, until the 56 days had elapsed, to dispose of their weaner or growing pigs.

Premises within infected areas other than those subject to Form A or Form D restrictions

a. Pigs could be moved to a slaughterhouse anywhere in Great Britain.

b. Breeding stock, weaners or store pigs could move to any premises within the same infected area.

c. In exceptional circumstances, that is when there were problems of overcrowding and adverse welfare, weaners and growers were permitted to move under licence to premises outside the infected area. Such movements were permitted only if the premises of origin was not within 3Km of premises under Form A restrictions, if the receiving premises had no breeding stock nor breeding herds within 1Km and if the premises of origin were found, on inspection by a veterinary officer within 24 hours prior to the movement, to be free from symptoms of PRRS. The receiving premises were placed under Form D restrictions which remained in force until all the pigs moved on from the infected area had been slaughtered.

By mid-July 1991 the epidemiological data which had accumulated indicated that the long distance spread of the infection had, in every case, been a consequence of the movement of infected pigs. Where foci of infection had been established in this way in areas of high pig density local airborne spread was a feature and several clusters of cases were developing. The pattern of spread, however, indicated that no dissemination of the agent was occurring by the airborne route over distances greater than 3Km. The size of our original infected areas had, therefore, been near the ideal and the enlarged Humberside infected area was almost certainly unnecessary as well as being a serious impediment to normal trade.

By 10 July 1991 30 Form A restrictions had been served. The sources of the infection were as follows:

Table 2.

primary cases	2	(7%)
pig movements	15	(50%)
airborne spread	7	(23%)
vehicle contact	1	(3%)
fattening herds	2	(7%)
unknown origin	2	(7%)
negative on serology	1	(3%)

The first case of airborne spread was PDR 4, a breeding herd immediately adjacent to PDR 1, the first reported case. The next was PDR 6, on which restrictions were served on 4 June 1991. This was a more puzzling case, the eventual elucidation of which gave a warning of even more problems

ahead in the control of PRRS. PDR 6 had not received pigs from infected premises nor was in it anywhere near known infection. A neighbouring finishing unit, on which there was no breeding stock had, however, received a delivery of 300 weaned pigs from the first primary case on 30 April, and had required treatment for pneumonia on 16 May (the date, incidentally, of our first reported case). The finishing herd in question was subsequently confirmed to have seropositive pigs, long after the slaughter of the weaners which had brought the disease into the area.

PHASE IV OF CONTROL

By mid-July it was becoming apparent that the controls which had been put in place on 13 June were, in the case of Humberside, restricting pig movements in an unnecessarily large area. Accordingly, on 17 July four small infected areas replaced the larger Humberside one, these covering only a fraction of the previous area. At the same time there were some minor relaxations in the control of movements, particularly of store pigs, as the contraction of the area, by reducing the number of available outlets, would otherwise have made disposal of such stock much more difficult. It remained the case, however, that store pigs could leave an infected area only if they were from premises more than 3Km from a holding where there was suspected or confirmed disease. Such movements continued to be subject to the earlier conditions of licensing, approval of the recipient herd and the imposition on it of movement restrictions. The only other pigs allowed to leave an infected area were those being transported direct to slaughter. We had now entered what I will call Phase IV of the control programme.

In October we had to confront two problems which were not new, but which were becoming more acute. The first concerned the welfare of pigs on restricted breeding farms which would normally have been producing stock for sale at store weight, but which, because of movement restrictions, were having to retain these animals to slaughter weight on premises without adequate accommodation or equipment. Pigs had been kept in emergency accommodation, often outside, and the dry summer had permitted this to be done without too many difficulties. But by now the weather was changing; rain would make outside pig keeping difficult on unsuitable land. Health and welfare problems were likely to develop on units which had become overcrowded; and there were, of course, socio-economic problems for producers in the infected areas which were adding to the pressures within the industry.

The second major problem was that the holdings on which disease had first been confirmed, including units which normally depended on income from sales of breeding stock, had now been closed up for over four months. Although the

Commission decision allowed the lifting of restrictions eight weeks after the return of an affected herd to clinical normality, we were far from certain that it would be safe to do that. Indeed, we had carried out sentinel trials on a number of herds which had had such a period of clinical freedom and found that seronegative stock added to known infected herds seroconverted within three weeks of their introduction. Limited serological surveillance had also revealed that the infection was considerably more widely dispersed than the clinical evidence suggested. Breeding herds, apparently free from disease, were found to have become infected, either by the movement on of breeding animals from sources subsequently shown to be diseased, or by local airborne spread. This was true also of a number of finishing units, none of which had shown more than the mildest of symptoms. Most alarmingly for the control of the disease, such holdings, infected but clinically healthy, were apparently potentially potent sources of the infection to neighbouring herds. The sources of several unexplained cases, remote from previously known foci of infection, were thus revealed.

The results of the serological survey are summarised in the following table.

Table 3.

Breeding herds		
No. sampled	No. positive	No. positive showing mild symptoms
22	12	1
Fattening herds		
No. sampled	No. positive	No. positive showing symptoms (increased coughing)
10	7	2

PHASE V OF CONTROL

It was by now apparent that, while the spread of PRRS could be slowed down, it could not be halted by the movement controls we had imposed. On 16 October 1991 a major alteration in the controls was introduced. All infected area restrictions were lifted as were most restrictions on individual herds other than those which applied to premises with suspected or confirmed disease. The restrictions on affected herds were to remain in place until eight weeks after the herd had been certified as free from symptoms of PRRS.

The control measures which were retained were more than enough to meet the requirements of Commission Decision 91/237/EEC, the intra-Community trade aspects which had been extended to include the UK by Commission Decision 91/332/EEC of 8 July 1991.

Movements permitted from Form A premises were:

a. Pigs for slaughter under licence direct to an abattoir.

b. Pigs for further fattening to any holding without breeding stock which would be placed under Form D restrictions until all pigs on the premises were licensed for slaughter or the Form A lifted on the farm of origin.

c. Breeding stock under licence only to other premises under Form A restrictions.

FURTHER EPIDEMIOLOGICAL CONSIDERATIONS

There is no evidence in this country, from other EC Member States or from North America, that artificial insemination is implicated in the spread of the PRRS agent. It would be unwise, however, to rule out this possibility completely until appropriate trials have been done. The agent, although not fully characterised at the time of writing, is believed to be an arterivirus and PRRS does, certainly, share some characteristics with equine viral arteritis, in which infective semen plays a major role in the maintenance and spread of the disease (Timoney & McCollum 1987).

Our experience has been that the disease is spread by direct pig to pig contact or by the airborne carriage of the agent over distances of up to 3Km or so. Airborne spread of the disease is difficult, of course, to demonstrate conclusively from field evidence. Using the data from Humberside, where the pig density is highest and where the majority of our cases have occurred, there are two problems of interpretation. The first is in defining the date of entry of the agent from the apparent date of commencement of clinical disease given the variation in the "lag time" which has been referred to earlier. The second is in determining whether the direction of spread is truly consistent with wind direction, given that the coastal plain of East Yorkshire is subject to very frequent short-term changes in wind direction. The Lelystad Institute have attempted, without success, to recover virus from air filters from houses in which acutely ill pigs were confined (Wensvoort 1991). Our tentative conclusions about the sources of infection in our cases are, however, remarkably similar to the quite independent assessment of the cases in Belgium. It is interesting to compare the first 100 reported cases in Britain with Belgium's 81 cases.

Table 4. First 100 reported cases of PRRS in Great Britain

Primary cases	2	(2%)
Pig movements	18	(18%)
Airborne spread	63	(63%)
Vehicle contact	2	(2%)
Fattening herds	3	(3%)
Unknown origin	4	(4%)
Negative on serology	8	(8%)

Table 5. 81 cases in Belgium in 1991

Pig movements	7	(9%)
Airborne spread	56	(69%)
Other contacts	3	(4%)
Unknown	15	(18%)

It is important to note that, of the Community countries which have experienced the disease, only the UK has used the serological test for confirmation of PRRS.

A comparison of Table 3 with Table 2 for the first 30 cases in Great Britain reveals that there was, over that period, a dramatic change from a majority of cases being associated with pig movements to the airborne route as the main mode of spread. This is further illustrated by the month-by-month figures for the percentage of cases due to pig movements and to airborne spread.

Table 6.

	Cases	Pig movements	Airborne
May	4	75%	25%
June	21	48%	19%
July	7	29%	57%
August	17	6%	82%
September	20	5%	70%
October	30	0%	83%

For the distances over which local airborne spread has occurred it is again interesting to compare our figures for cases up to the end of October 1991 with those for Belgium over the same period.

Table 7. Distances over which airborne spread has occurred

UK (61 cases)		Belgium (56 cases)	
Average <1.5Km		Average 1/3Km	
< 1Km	57%	< 0.5Km	50%
1-2Km	31%	0.5-2Km	40%
2-3Km	11%	> 2Km	10%

There has been no indication from our observations that contaminated vehicles, feedstuff or equipment have been associated with the spread of the agent nor that human contacts, birds or other vertebrates have been responsible. It would appear that such means of introducing the infection from the continent can equally be ruled out. It seems implausible that airborne dispersal of the agent could account for its introduction to Humberside from continental Europe, across a distance of 400Km or more. The UK had no imports of live pigs, semen or embryos from countries known to have had the infection during the 12 months preceding the start of our epidemic, which leaves us with no explanation for the entry of the disease to Britain.

CONCLUSION

Porcine reproductive and respiratory syndrome is a disease ill-suited to control by movement restrictions because of several of its epidemiological features:

a. airborne spread is common;

b. infected herds do not invariably exhibit clinical signs of the disease;

c. herds infected sub-clinically can be a source of infection to other susceptible herds;

d. there is evidence of long term persistence of the agent in infected herds.

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POULTRY EPIDEMIOLOGY

NEWCASTLE DISEASE - RECENT EXPERIENCES DURING AN OUTBREAK IN NORTHERN IRELAND

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Newcastle Disease, in scientific terms, is a disease of poultry caused by a paramyxovirus type-1 (PMV1) but for international control purposes it is now accepted that Newcastle Disease is any infection by an avian PMV1 with an intracerebral pathogenicity index (ICPI) of over 0.7. This definition is contained within the current "Draft for a Council Regulation introducing Community measures for the control of Newcastle Disease". Under EC Council Directive 90/539/EEC a Member State or Region can claim freedom from Newcastle Disease provided the following elements apply:-

- no Newcastle Disease shall have been detected in the previous 12 months;
- vaccination is not permitted;
- vaccinated birds shall not be imported;
- all breeding flocks shall be monitored at least once a year.

The island of Ireland (Northern Ireland and the Republic of Ireland) has previously practised a non-vaccination policy and does not permit the import of vaccinated birds. This Newcastle Disease-free status has resulted in there being a poultry population which is fully susceptible to PMV1. Occasional outbreaks have occurred in Northern Ireland and this paper discusses the most recent outbreak (1991) and the successful eradication of the infection.

PREVIOUS OUTBREAKS

1949

Localised outbreaks occurred in the north east of the Province and epidemiological evidence indicated that infection was almost certainly introduced to the poultry industry (then extensively reared) by sea birds from concurrent outbreaks in Scotland.

1964

Localised outbreaks again occurred in the north east of the Province but were not associated with any clinical disease (ICPI - 0.00). This strain, the Ulster 2C, was probably introduced by wild birds. Currently, such infection would not result in any stamping out action under the proposed Newcastle Disease Control Regulation of the EC.

1967

A small localised outbreak occurred in the mid south region of the Province in backyard flocks and was associated with disease in an illegally imported parrot.

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1973

A more severe outbreak occurred in the intensive poultry industry involving 29 flocks in the east of the Province. The virus involved was highly virulent and wind borne dissemination was evident subsequent to introduction. As there were three primary outbreaks it is possible that the PMV1 was introduced via feedingstuffs but this possibility was not fully investigated at the time. With the aid of a slaughter policy and ring vaccination a Newcastle Disease-free status was achieved once more.

This Newcastle Disease-free status was monitored by:-

- testing 10 per cent of all breeding poultry, at least once per year;
- testing 100 per cent of all imported poultry; and
- testing all poultry carcases and sera submitted to the Veterinary Research Laboratories which offer a free diagnostic service.

1991 OUTBREAKS

The Northern Ireland intensive poultry industry consists of 3.7 million laying birds, 1.0 million breeding birds and approximately 5.5 million broiler birds.

In mid March, in a 12,000 commercial laying bird unit, a producer reported a slight drop in egg production associated with unpigmented eggs and soft shelled eggs. The problem was first noted in a few cages at one end of the house and spread occurred very slowly along the row of cages. All birds remained clinically healthy. Sera were submitted to the Veterinary Research Laboratories to investigate Egg Drop Syndrome and Infectious Bronchitis as the possible cause of the problem and in accordance with standard surveillance procedure, they were also examined for Newcastle Disease antibodies. Some were found to be positive.

An epizootic disease investigation was immediately set in motion and restrictions were placed on the premises. Further blood samples and carcases were submitted to the laboratories and on 19th March a PMV1 was isolated and subsequently shown to have an ICPI of 1.66. The PMV1 was typed as a pigeon paramyxovirus at the Veterinary Research Laboratories and this was confirmed by the EC Reference Laboratory at Weybridge. Following confirmation of disease the birds were all slaughtered.

Further outbreaks occurred, all involving commercial laying flocks and all exhibiting similar clinical signs - drop in production, unpigmented eggs, soft shelled eggs and very slow spread within a house. Clinical evidence indicated that infection tended to remain localised within a house and this was supported by serological examination when less than 1 per cent of birds within an affected house proved positive. Such birds were invariably located in the clinically affected region of the house. In three of the six outbreaks repeated sampling had to be undertaken before infection could be confirmed. The first five outbreaks were all reported between the 12th and 23rd of March and the sixth outbreak was first reported on 13th May. The six outbreaks were geographically separated and occurred in five of the six Counties which make up the Province of Northern Ireland. Approximately 200,000 laying birds were slaughtered during the course of the outbreak. Based on clinical examination and serological testing of birds within each 10 kilometre zone there was no evidence of lateral spread from any of the six outbreaks. Neither broiler nor breeding birds were infected.

EPIDEMIOLOGICAL INVESTIGATIONS

In attempting to eradicate the 1991 outbreaks of Newcastle Disease, defining the source of the infection was recognised as a high priority. Possible sources such as water supply, personnel movements, movements of vehicles, equipments such as egg trays and trollies and wild birds were investigated. It was concluded that such sources were unlikely, either because all houses were on mains water supply or because no contact with any possible source of infection either inside or outside Northern Ireland could be established.

Epidemiological data from the six outbreaks suggested that contaminated feedingstuffs may have been the source of infection. The significant factors which led to this conclusion were as follows:-

- identification of the virus in all six outbreaks as pigeon PMV1;
- all outbreaks involved intensively kept cage layers with no direct contact with pigeons or other wild birds;
- Newcastle Disease in intensively reared poultry caused by pigeon PMV1 would appear to be a rare occurrence. Only two previous outbreaks have been reported - in Great Britain and Austria. On both occasions the source of infection was identified as contamination of feed by feral pigeons;
- all six producers fed non-heat treated feed: no outbreaks were found in birds receiving heat treated feed;
- four of the six outbreaks were supplied by one feed mill;
- the remaining two outbreaks were supplied by two further feed mills but several of the feed ingredients were from a source common to the other four;
- the history and clinical signs were similar in all six outbreaks.

It was hypothesised that the outbreaks represented an extended, common source epidemic with contaminated feedingstuffs as the source of the pigeon PMV1.

INVESTIGATION OF FEEDINGSTUFFS

The raw materials for manufacture of poultry layer rations were sourced primarily from flat stores and silos in Belfast Docks, from where they were taken to the mill for blending into final feed. Imported raw materials for inclusion in animal and poultry rations were also stored in silos and flat stores in Belfast Docks. It was highly unlikely that the final feeds were contaminated on the farm or in transit from the mill to the farm. Vehicles were closed after loading at the mill and on the farm the feed was blown into completely enclosed bins. It was also highly unlikely that contamination occurred in the mills. These were almost completely enclosed and pigeons rarely gained access to the premises. In addition, finished feeds for bulk delivery were generally made up to order and were not stored at the mills.

Silos were filled directly from the hold of the ship and vehicles were filled from the silos by gravity. The silos were totally enclosed although pigeons did feed at the inlet and outlet points of spillage. Spilled material, on occasions, was swept up along with pigeon faeces and put into the vehicle. The flat stores consisted of large sheds inside which the various raw materials were stored in large separate heaps. The

raw material was transferred from the hold of the ship to the shed by vehicles. Vehicles collecting material for the manufacture of feeds were driven into the shed, loaded by mechanical shovel and driven out again.

Ingredients used in the manufacture of layer feeds such as pollards, grain, maize, maize gluten and soya were imported into Northern Ireland, either directly (pollards from West Africa and Europe, grain from the Republic of Ireland) or via Rotterdam. Some materials were also imported from Great Britain (maize germ). Conditions of storage in countries of origin or transit could not be ascertained in most instances.

Examination of storage facilities at Belfast Docks revealed that one flat store was in a state of repair which allowed pigeons more or less free access to the premises. Indeed, from observation and questioning it appeared that pigeons were virtually permanently resident in the store to the extent that they actually nested there. Apparently it was not unusual to find pigeon eggs and occasional carcases in the raw materials stored within. Inspection of raw materials in the store showed considerable evidence of faecal contamination.

Epidemiological investigation of the four outbreaks supplied from the common mill revealed that, at the time of possible exposure of the four flocks to infection, the only material in the ration sourced from this particular store was pollard (fine bran). Investigation of the other two outbreaks revealed that the mills implicated also obtained pollard from the same flat store. It was noted that the mill associated with four of the outbreaks sourced almost all its pollard from this one flat store whereas the other two mills obtained most of their pollard from other stores. A fourth mill obtained pollard from this flat store, but it only supplied less than 0.1 per cent of the tonnage of layer rations. All other major mills (six) and integrated producers did not obtain pollard from this flat store and there were no outbreaks associated with usage of their products.

All the other ingredients in layer rations produced from the three mills implicated were also investigated and compared with major feed compounders who did not have any outbreaks associated with their product. Detailed examination revealed that the use of imported pollard was consistent with the distribution of the outbreaks. This was not true for any other single ingredient. However, the possibility remained that more than one contaminated feed ingredient may have been responsible for the outbreaks.

Evidence indicated that raw materials (most probably pollard) were the source of virus for the finished feed but it was not possible to determine whether:-

- the raw materials were contaminated prior to arrival in Northern Ireland or,
- the raw materials were contaminated subsequent to arrival in Northern Ireland.

Pigeon carcases and sera were collected from the vicinity of Belfast Docks. Although virus was not isolated from the pigeon carcases 22 of 40 bloods were positive for pigeon PMV1 antibodies. In addition, virus was isolated from pigeon carcases obtained from within the Greater Belfast area. However, it was not possible to conclusively

demonstrate whether primary contamination of the raw materials occurred within, or prior to arrival in Northern Ireland. Nevertheless it was recognised that, due to an infected feral pigeon population, there was the potential for further contamination and any future preventive strategy must take credence of it.

CONTROL AND ERADICATION

Measures employed to control and eradicate the disease were based on current Department of Agriculture for Northern Ireland policy and on the draft EC proposals. These include slaughter and disposal of carcases, cleansing and disinfection of infected premises, establishing 3 and 10 km zones around each outbreak and clinical and serological monitoring of flocks within these zones.

In recognising that contaminated feedingstuffs were the source of infection for poultry, action was implemented by 30th March aimed at eliminating the risk of further outbreaks:-

- all silos and stores must be bird and vermin proofed;
- all poultry feedingstuffs must be heat treated to a minimum of 70°C for 1 minute (Poultry Feedingstuffs Order (Northern Ireland) 1991).

This action was taken following full consultation with the industry but, recognising that there was not sufficient heat treating capacity immediately available, an exemption was provided. This permitted (until 31st August 1991) the use of non-heat treated feed provided that the raw materials came from and were stored in bird and vermin proof stores.

As a result of the above measures there were no further outbreaks. Only in the final outbreak were birds receiving heat treated feed but there was evidence that infection was introduced by residual non-heat treated feed in the feeding system.

FUTURE POLICY

Having re-established a Newcastle Disease-free status within the poultry industry in Northern Ireland it is recognised that several routes of infection are possible which could result in the reintroduction of PMV1. These include:-

- Live poultry (including exotic birds) and poultry products. Protection is already afforded by prohibition, or import with certification and/or quarantine as permitted by EC and other international provisions.
- Wild birds. This is most likely to be avirulent virus. Furthermore, most of our industry is intensive and the houses are wild bird proofed and indeed this is a legislative requirement for all breeding poultry following the 1964 outbreak.
- Vehicles and equipment. Legislative control measures exist and are policed at points of entry into Northern Ireland.
- People. While it is obviously impossible to legislatively control the movement of people, our industry is aware of the risk and takes appropriate precautions. Furthermore, the Department exercises an awareness programme including announcements and posters at the time of entry into Northern Ireland.

- Contaminated feed, including constituents. It is impractical to control the import of such basic commodities as the constituents of feed, any of which can come from areas of the world where virulent Newcastle Disease is endemic. In addition, contamination of products within Northern Ireland via feral pigeons remains a possibility.

Thus contaminated feed constitutes a major potential source of introduction of infection. The Department therefore concluded that an additional, effective method of combatting this source was to require heat treatment of poultry feed sufficient to kill PMV1. Advantages afforded by heat treatment are as follows:-

- Contaminated raw materials for feed will continue to be a major potential source of introduction of PMV1.

- However where the finished feed is heated to 75°C for 1 minute (Poultry Feedingstuffs (Amendment) Order (Northern Ireland) 1991) any contaminating PMV1 should be inactivated. By doing so, a major route of introduction, from within and outside Northern Ireland has been effectively removed.

- If a Newcastle Disease-free status is not achieved or is lost, live birds and hatching eggs may be imported from other Member States and in the process other economically important diseases may be introduced for the first time to Northern Ireland. These include the highly virulent Infectious Bursal Disease virus which can result in mortality of 20-50 per cent of birds even up to 16 weeks of age.

- All birds, including broilers and backyard flocks, will receive feed free from PMV1.

The Department of Agriculture for Northern Ireland considered whether vaccination was a possible alternative measure to afford protection to the poultry industry. However, a vaccination policy has the following disadvantages:-

- Compulsory vaccination is not practised in other Member States except in the Netherlands. If vaccination were to be introduced it would be on a voluntary basis and it is unlikely that all poultry would be regularly vaccinated.

- Vaccination will protect the majority of vaccinated birds from clinical disease but not from infection. Such infected birds can excrete virus to infect other birds.

- EC demands action to be taken, not simply on the presence of disease, but on the presence of virus. Thus even though vaccinated birds may not show clinical signs, isolation of virus will result in the full application of EC Newcastle Disease control measures.

- Backyard flocks would not be vaccinated and will be totally susceptible. If disease or virus is found the full control measures will apply (declaration of infection area, slaughter of infected birds, cessation of all exports from infected zones, etc). Backyard flocks can also act as a source of infection for the large integrated poultry industry with Northern Ireland.

- Non-heat treated feed, even if derived from bird proofed stores and silos can still be contaminated prior to importation.

- A vaccination policy will result in loss of a Newcastle Disease-free status and with it the loss of import protection from several economically important diseases afforded through Article 12 of Council Directive 90/539/EEC.

- Broilers would not be vaccinated but would have some maternal immunity from the parent. Whilst such protection will be adequate to deal with low levels of virus challenge, it is well recognised that high levels can overcome such immunity and result in both infection and disease.

SUMMARY

The poultry industry within Northern Ireland, supported by the Department of Agriculture for Northern Ireland perceive commercial and economic advantages in retaining a Newcastle Disease-free status. In the light of the recent outbreaks and the potential for the reintroduction of PMV1 to the intensive poultry industry, from within and outside Northern Ireland, the industry are seeking additional preventive measures. It is concluded that such additional, practical measures are afforded by bird and vermin proofing of silos and stores and effective heat treatment of all finished poultry feedingstuffs. Furthermore, such a heat treatment policy would, more readily, permit the introduction of effective heat treatment to eliminate Salmonellae from finished feed if our entire poultry industry were to require such feed in the future.

SALMONELLA - THE FEEDSTUFFS CONNECTION

R.H. DAVIES*

Salmonella infection is widespread in all types of wild and domestic animals. Some serotypes are relatively host specific, e.g. Salmonella cholerae-suis in pigs. Others, notably Salmonella typhimurium have a wide host range including man (Wray, 1989).

In animals and humans salmonellosis gives rise to a wide spectrum of clinical conditions which ranges from the symptomless carrier state through varying degrees of enteritis to septicaemia and death. Young, immuno-deficient or stressed individuals suffer most severely. The weight of challenge is important in determining the severity of salmonella outbreaks on farms and disease is often more prevalent and difficult to control in large, intensive livestock units. The exception to this is where animals are efficiently separated from their faeces, as in battery cages.

Poultry are usually symptomless carriers of salmonellae, the problems of egg infection and amplification of salmonellosis during broiler processing are well known.

Following the rise in reports of S. enteritidis infection in poultry and man R&D was commissioned at the CVL to undertake research into the following areas:

1) Development of a live vaccine.
2) Development of a killed vaccine.
3) Development of serological tests.
4) Descriptive epidemiology of Salmonella enteritidis in the poultry industry.
5) Salmonella contamination of animal feeds.

The author has had responsibility for the feed segment of the project, which will be discussed in more detail later.

Table 1 provides an analysis of the results of serotyping of cultures at CVL. There has obviously been an increase in statutory monitoring of poultry flocks during the period between 1989 and the present which has resulted in more isolates being submitted. S. enteritidis is by far the most frequently isolated serotype from poultry. Many other types are still prevalent and all are capable of causing food poisoning in humans.

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Table 1. Serotyping results for Salmonellas isolated from poultry: 1988-1990 (MAFF 1990)

Serotype	No. of Cultures		
	1990	1989	1988
S. enteritidis	3509	1640	509
S. typhimurium	898	754	163
S. indiana	495	612	60
S. newport	686	288	177
S. heidelberg	225	252	20
S. senftenberg	338	204	90
S. bredeney	297	153	4
S. kedougou	124	150	15
S. hadar	106	117	45
S. agona	185	111	21
Other serotypes	1740	989	222
Total	8603	5270	1326

Many studies have shown the link between animal salmonellosis and the consumption of contaminated feedstuffs (Boyer et al., 1989, Kamplemacher 1984, Williams 1981, MacKenzie & Bains 1976, Taylor et al., 1965, Gordon 1971, Williams & Hobbs 1975). International trade in animal and vegetable by-products has resulted in worldwide dissemination of new salmonellae, for example, S. agona in fishmeal (Clark et al., 1973).

There is constant debate about the significance of salmonella in animal feeds. It is true that in most cases it is difficult to artificially infect healthy adult animals with the levels of salmonella normally found in finished rations. Often numbers of salmonellae are so low (< 3/100g) as to escape detection by all but the most sensitive techniques (Stott et al., 1975).

When conditions are warm and moist in storage bins salmonellae can multiply rapidly to reach infective doses. This commonly occurs in pockets within feed bins wherever there is condensation or leakage of rain. A similar situation occurs in ad-lib hoppers or poorly cleaned troughs where a build-up of material moistened by saliva and excreta occurs.

It has been shown that day-old chicks can be experimentally infected by feed contaminated with 10 organisms per 100g (Hinton 1988). Levels of salmonellae greatly exceeding this has been regularly found in certain chick starter rations. Infection of a single chick can result in massive faecal excretion of salmonellae. The resulting environmental contamination disseminates infection throughout the flock. A similar situation may apply to a lesser degree, in laying flocks approaching the end of their production cycle when there may be a decrease in immunity which allows salmonella infection to become established with a greatly reduced infective dose. Further work is necessary to define other factors which may facilitate colonisation by low numbers of organisms.

ANIMAL FEED SURVEILLANCE

Processed animal proteins

Statutory monitoring, under the Processed Animal Protein Order 1989, has shown a gradual decline in the contamination rate of samples taken from 10% in 1982 to 3% in 1991.

During the same period the contamination rate of imported processed animal protein samples rose from 12% in 1982 to 24% in 1988 then diminished to 13% in 1991.

Other feed ingredients

In a survey of 1042 ingredients carried out at CVL it was found that certain vegetable ingredients, noteably palm kernel, rape, rice bran and cotton seed tended to show a high rate of contamination, often with very large numbers of Salmonellae.

Rape is a common low cost protein ingredient of many animal rations, including poultry feeds. The combination of high contamination rate, large numbers of organisms present and the large volumes of rape used in feed mills means that rape is the highest risk ingredient used at present.

As with other oil extracted products it is common to find that certain rape processors have their own specific salmonella serotypes. This is because of multiplication and persistence of a certain type within the processing plant. Such persistence sites are normally within the cooling system and are extremely difficult to eliminate. Contaminated products can therefore produced on a regular basis for years.

At present there is no statutory requirement for testing of vegetable feed ingredients. It is likely that an improved code of practice will be formulated in the near future. It is the responsibility of feed compounders to adequately screen their ingredients and to boycott suppliers of consistently contaminated materials. It is essential that good quality laboratories are retained for their services as isolation of salmonella from feedstuffs is not as simple as it appears.

No S. enteritidis has been isolated from any ingredients in this survey. although S. typhimurium is occasionally isolated from cereals. This is not surprising as grain is often stored in open heaps on farms. Frequently buildings which have housed cattle during the winter are used for short term storage. It is also common for the same handling equipment to be used to move grain and to clean out animal housing.

FINISHED FEEDS

Compound feed survey

A finished feed survey involving 25 feed compounders throughout the country was undertaken. The interim results are shown in Table 2.

Table 2. Finished feed survey - Compound rations

		No. of samples	No. +ve	% +ve
Compound feed mills in survey	- pellets	1060	36	3.39
	- meals	448	36	8.04
Compound feed mills outside survey	- pellets	1061	114	10.74
	- meals	46	9	19.56
C.V.L. rations (Bagged rations from various producers)	- pellets	433	0	0
	- meals	10	0	0

These samples were all taken from commercially produced feeds. The rate of contamination of pellets from the feed mills participating in the survey was low at just over three per cent. The contaminated pellets were produced by three companies which were subsequently identified as having persistent cooler contamination problems.

The rate of contamination of meals was much higher and was a problem in most of the mills. Those dedicated to specialist poultry rations used organic acid treatment for much of the meal output and had far less contamination than average with 0-2 isolates per visit compared to 10-14 from most mixed feed mills.

As part of epidemiological investigations of poultry flocks we were able to look at samples of feeds as delivered to the various farms from feed compounders who had declined to participate in the survey. The contamination rate in these cases was much higher. In two of these cases access to the feed mills was later made available and heavy persistent contamination of the plant confirmed. The rate of contamination of finished rations from compound feed mills ranged from 0 to 23.7%.

The CVL rations were mainly bagged pellets, mostly originating from mills which were known to be free of serious salmonella problems. The large number of salmonella-free samples does demonstrate the possibility of producing non contaminated rations under commercial conditions.

Table 3. Finished feed survey - Farm mixed rations

	No. of samples	No. +ve	% +ve
Pellets	84	1	1.19
Meals	208	19	7.33
Ingredients	113	11	9.73

Table 3 shows the contamination rates of samples of home mixed rations received from 21 farms throughout the country. This work is at an early stage and it is hoped to extend it in the future. It would appear that, despite being supplied with ingredients which, on average, have a higher contamination rate than that of feed compounders, the finished products are cleaner. The range of contamination rates for finished products varied from 0 to 100%.

Having instigated the feed and ingredient surveys further work involved detailed monitoring of the feed mill environment and equipment. Figure 1 shows an extremely simplified diagram of a typical feed mill.

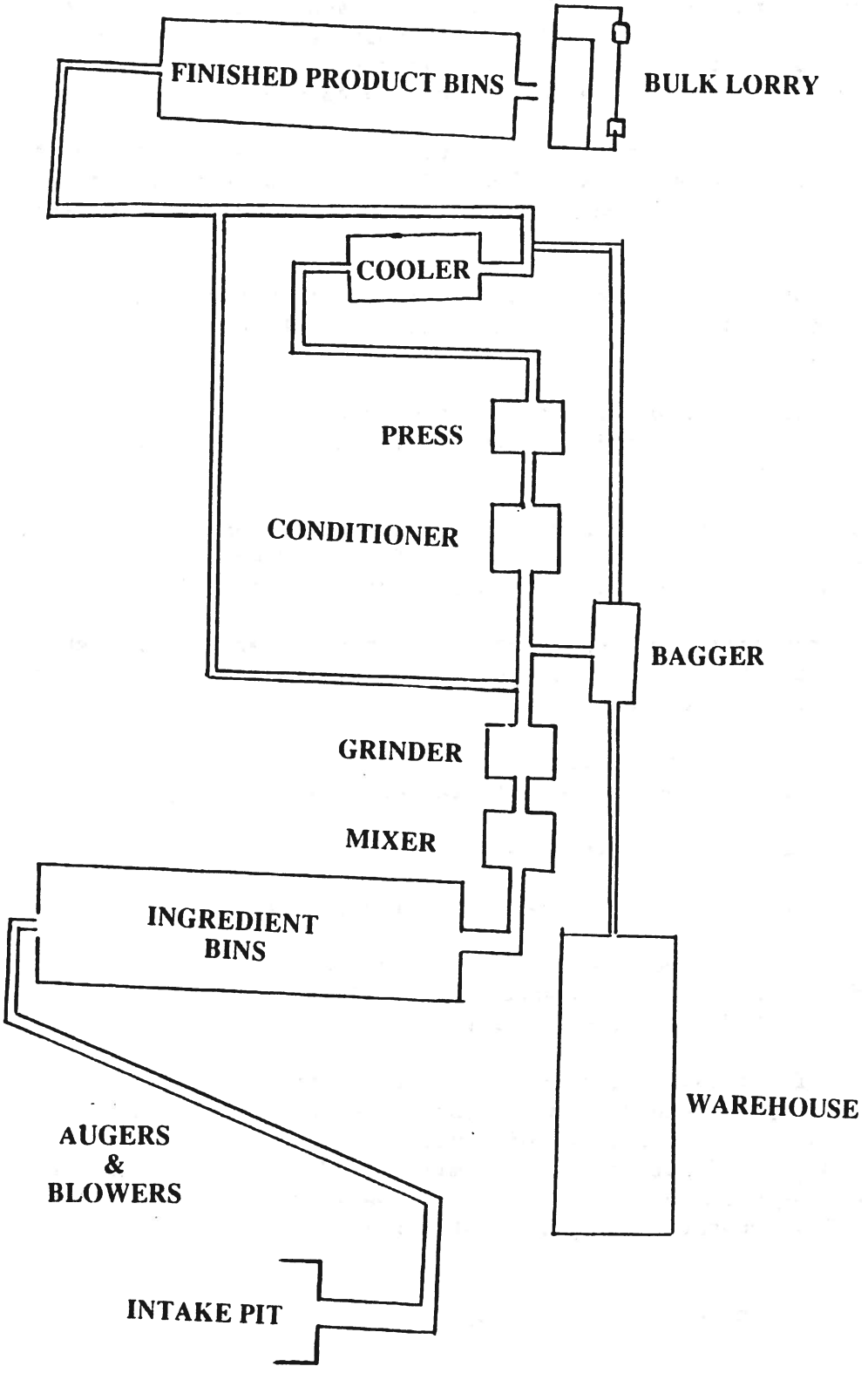

Figure 1 - FEED MILL DIAGRAM

Major ingredients are delivered in bulk into an intake pit from where they are transmitted for short term storage to ingredient bins. The ingredients are weighed, mixed and ground. This produces a meal which can be bagged or directed to finished product bins. Some poultry meals are treated with organic acids to reduce salmonella levels which is often unsuccessful. If a pelleted ration is to be produced the ground material is conditioned by steam and then forced through a die by rollers in the press. The combined action of steaming and frictional heat from the pelleting process reduces bacteria levels in the feed. It is claimed that conditioning temperatures of at least 85°C for 1 minute are necessary for complete elimination of salmonella from feed (Liu et al, 1969). In practice lesser temperatures and conditioning times appear to be effective unless there is a very high level of ingredient contamination. The low temperatures used for some ruminant rations in order to maintain pellet quality are often ineffective in eliminating salmonella.

After pelleting the hot moist feed is cooled and dried by forced or natural air circulation in a cooler. The finished product is then either bagged or stored in finished product bins to await delivery to farms by bulk lorry.

Sampling of fresh aggregate and spillage from the sites shown on the diagram was carried out. Four patterns of distribution of contamination were identified i.e.:

1. Nil or very few isolates - these were typically specialist pig or poultry ration mills. This correlated with a low level of finished ration contamination.

2. Contamination concentrated at ingredient end of mill. This was related to a high rate of ingredient contamination and contamination of finished meals rather than pellets.

3. Contamination concentrated from the cooler to finished product areas. This was associated with a higher rate of contamination of pellets rather than meals.

4. High level of contamination throughout. This type of mill is regularly producing both contaminated meals and pellets.

The main problem areas encountered were:

a) Use of highly contaminated ingredients.
b) Use of kettle type conditioners.
c) Use of inadequate conditioning temperatures.
d) Use of coolers conducive to salmonella persistence.
e) Wet disinfection of lorries.

The use of aggregate samples of ingredients and finished rations was found to be a poor method of detecting salmonella problems in feed mills. This is because of dilution of contaminated samples and inclusion of antibiotic medicated rations in the mix. Monday morning start-up rations, taken after the weekend shut-down period, were good indicators of potential problems. Environmental monitoring at six key sites i.e.:

1. intake pits
2. ingredient bin auger spillage

3. grinder spillage
4. cooler output spillage
5. finished product bin auger spillage
6. bagger/bulk gantry spillage

was the best indicator of the distribution and origin of salmonella contamination within a mill. These samples plus start-up samples (non-medicated) could be taken on a regular basis for more effective monitoring of feed mills.

Table 4 shows the pattern of contamination in two feed mills which are regularly producing both contaminated meals and pellets.

Table 4. Distribution of Salmonella in two feed mills

Sampling site	Type of Salmonella	
	Mill A	Mill B
Intake	)S. newport)S. meleagridis	)S. montevideo)S. coeln
Ingredient bins	S. newport	)S. ohio)S. kedougou
Mixer	S. mbandaka	S. kedougou
Grinder	)S. cubana)S. godesberg	)S. tennessee)S. cubana)S. idikan
Press	S. mbandaka	)S. tennessee)S. agona)S. ohio
Cooler	)S. mbandaka)S. kedougou	)S. ohio)S. tennessee)S. kedougou
Finished product bins	-ve	S. ohio
Warehouse/bagger	S. mbandaka	S. ohio
Gantry	)S. mbandaka)S. tennessee	S. cubana
(Kettle)	N/A	S. ohio

Mill A was sampled on three occasions. A high level of contamination was found at each of the visits. The output of this mill was sampled on a regular basis. It was found that 5% of the pellet output was contaminated with S. mbandaka on a long-term basis. The appearance of this serotype in poultry on a unit supplied by this mill was also demonstrated.

Mill B has been associated with production of pellets contaminated with S. ohio for many years. This serotype is not particularly common in feed or in animals. Several poultry units receiving feed from Mill B have had persistent problems with S. ohio in the birds. In future work it is hoped to substantiate links between feed and animal by the use of genetic finger-printing techniques (plasmid profile and restriction enzyme digest analysis).

Observations in these feed mills and others have demonstrated the importance of persistence and multiplication of salmonella in pellet coolers. Feed produced during the first hour following the weekend shut-down period is particularly at risk. These rations are usually not included in the aggregate samples used for testing under the code of practice because of the early start-up times (5.00-6.00am).

In both Mills A and B there is a high rate of contamination throughout the mill representing both use of salmonella contaminated ingredients as well as persistent cooler contamination. Only a tiny fraction of the available spillage and aggregate present was sampled during the visit which means that actual contamination rates of various areas is likely to be much higher.

Table 5. Mill C - Serial environmental sampling

Intake	Blender	Grinder	Press	Cooler	Bagger
-	tennessee	-	-	-	-
-	-	mbandaka	-	-	-
mbandaka	-	idikan	-	-	-
indiana	indiana	-	-	-	-
-	new brunswick	-	mbandaka	-	-
16:-:-N.M.	16:-:-N.M.	lille	oranienberg	-	virchow livingstone
-	-	-	-	-	-
-	-	-	-	-	-
gold coast	virchow	-	-	virchow	agona gold coast
-	-	-	-	-	-
8,20:i:-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
gold coast	-	-	-	-	-
-	infantis	agona	-	-	-
-	-	gold coast	-	-	-
gold coast	-	-	-	-	-
-	-	-	-	-	-

Table 5 (cont.)

Intake	Blender	Grinder	Press	Cooler	Bagger
-	kentucky cubana	kentucky	-	-	-
gold coast	mbandaka	-	-	-	-
gold coast	-	-	tees	-	-
gold coast	-	-	virchow	-	-
-	-	-	-	-	-
-	-	-	-	-	-
mbandaka	-	-	-	-	-
typhimurium	-	living-stone	-	-	virchow
livingstone	-	mbandaka	-	tees derby	-
-	-	-	-	living-stone	-
-	-	derby	-	-	-
enteritidis	typhimurium		-	-	-
tennessee	-	-	-	-	-
-	tennessee	-	-	-	-
indiana	-	-	-	-	-
-	-	-	-	-	-
gold coast agama	-	-	-	-	-
-	-	-	meleagridis	-	-
-	-	mbandaka	tennessee	-	montevideo
-	-	-	-	-	-
typhimurium idikan	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
ohio+cubana	-	-	-	-	-

Table 5 shows the results of a serial weekly sampling study in Mill C. This mill shows a different pattern of contamination. There are a wide range of serotypes contaminating the early parts of the mill. This reflects regular use of highly contaminated ingredients. Contamination of the coolers is transient rather than persistent with no regular pellet contamination problem. Mill C was the only mill in our survey where S. enteritidis was found.

An interesting feature of this mill is the frequent isolation of S. goldcoast. This is an uncommon serotype, especially in feed. As

co-operation by this mill was limited to environmental sampling plus access to in-house test results we were not in a position to identify the source of this salmonella. S. goldcoast has never been isolated during the companies own tests despite fairly comprehensive sampling of mill samples, ingredients and finished rations. Our survey also detected S. goldcoast in Mill C's finished meals indirectly on three separate occasions involving two farms supplied by the company.

Salmonella isolation methodology

Mill A was not aware of its salmonella problem at all, Mill B was never able to isolate S. ohio from its feed or mill samples and Mill C had failed to identify S. goldcoast at any time. Similar observations are common throughout our survey and must cast doubt on the efficacy of some present monitoring practices.

During the course of this study we have developed a more sensitive version of the standard cultural technique (Anon, 1989) for animal proteins. Table 6 outlines the steps in the standard and revised technique.

Table 6.

	Standard Method	Revised method
DAY ONE	PRE-ENRICHMENT	
	2 x 25g sample. 225ml BPW. 37°C, 18hr incubation.	Same
DAY TWO	SELECTIVE ENRICHMENT	
	0.1ml above— 10ml RVS Broth. 42.5°C, 24hr incubation.	1M Broth + 100ml RVS 41.5°C, 24hr incubation.
DAY THREE	24hr PLATING OUT	
	10 Microlitres streaked over two BGA plates. 37°C, 24hr incubation.	10 Microlitres streaked over one Rambach agar plate. 37°C, 24hr incubation.
DAY FOUR	Repeat Day three procedures - confirm suspicious colonies on Day three plates.	
DAY FIVE	Confirm suspicious colonies on Day four plates	

BPW = Buffered Peptone Water (Oxoid CM509)
RVS = Soya based Rappaports-Vassiliadis broth (Oxoid CM669)
BGA = Brilliant Green Agar (Modified) (Oxoid CM329)
Rambach Agar (Technogram - Patent pending)

The new method uses a tenfold increase in inoculum from the pre-enrichment broth. The selection enrichment incubation temperature is reduced to minimise loss of salmonellae. With RVS broth it is particularly important to control incubation temperature very carefully as one degree

increase results in death of some salmonellas and one degree fall results in overgrowth of low numbers of salmonella by competing organisms.

Rambach agar allows the use of one plate rather than two, with consequent savings in time and resources. This is because there is less overgrowth by competitive flora on this medium and the colour differentiation of salmonella from non-salmonella is improved. Another advantage is the high specificity. The characteristic colonies are easy to distinguish, with an extremely low false positive rate. This means that time and reagents used to confirm suspicious colonies as salmonella are markedly reduced.

Some evaluation of rapid salmonella detection methods has been undertaken as part of this study. It would appear that all tested so far lack the sensitivity of the improved cultural method in the face of the high levels of competitive flora found in animal feeds.

A method involving abbreviated pre-enrichment and semi-solid Rappaports medium with presence of salmonella confirmed by latex kit is to be investigated. This technique is capable of giving results in under 36 hours and has proved extremely sensitive in testing of poultry house environmental samples.

Discussion and conclusions

Although it is a relief that very little S. enteritidis is present in the animal feed industry now this may be purely fortuitous as present control measures allow access to many other salmonellas. It is possible that, unlike the common feed serotypes, S. enteritidis does not survive well in feedstuff materials unless present in large numbers or low levels of competitive flora are present. This may be because of tissue adaptation in order to exhibit enhanced invasiveness.

Many poultry farmers are worried about the chance of introducing S. enteritidis into their flocks through feed. This is fairly unlikely at present although there is a possibility that the organism will increase in the environment as a result of disposal of effluent, litter, dung and dust from the poultry industry. Similarly an increase in infection of wildlife may occur and lead to increased contamination of grains and other ingredients in storage. These factors may result in S. enteritidis assuming greater importance in the feed industry.

Having experienced the sudden rise in S. enteritidis PT4 in the poultry industry and in humans we must be aware of the possibility of this happening again with other serotypes. It is therefore most important to control salmonella by all possible routes.

Salmonellae are ubiquitous organisms so it is unrealistic to expect total eradication from the food chain. There are areas where regular high levels of contamination are allowed to exist both in the animal production industry and the feed trade. This is where control measures should be focused.

As with all disease control strategies it is necessary to start at the beginning of the chain which, in the feed industry, means ingredients. Feed compounders and home mixers have a right to be supplied with materials which are not grossly contaminated with salmonella. This means that sources of

regular contamination must be identified and boycotted by purchasers. In this area improved bacterial isolation methods and independent sampling and testing are necessary for all imported and home produced ingredients and ingredient suppliers. Results of testing should be made publicly available so that purchasers of ingredients can exert economic pressure which will eliminate persistently contaminated sources.

If clean ingredients are used then the tremendous effort that goes into feed mill hygiene become less important for salmonella control though dust levels must be kept low for personnel safety. It was found in this survey that there was no correlation between standards of cleanliness or freedom from either birds or rodents and levels of salmonella contamination. In one case there was a gross rat infestation throughout the premises such that spillage samples taken consisted largely of rat droppings. This mill had one of the lowest contamination levels of any in the survey because of careful ingredient purchase and absence of cooler problems.

Feed mills become important in gross amplification of infection when persistent contamination of coolers occurs. This depends on the type of cooler used and the conditioning system. Box and vertical coolers were found to give rise to more problems than horizontal coolers. the presence of a kettle conditioning system was always associated with subsequent cooler contamination.

It is important to identify intrinsically contaminated feed mills and deal with the problem. This may involve replacement of equipment. Often a combination of clean ingredients, higher pelleting temperatures, elimination of kettles, thorough physical cleaning of aggregate followed by passage of acid treated course bone meal and fumigation can be successful in eliminating persistent salmonella.

Most feed compounders are keen to address their salmonella problems but are often not aware of the extent of contamination. This is when improved testing is important. The availability of a troubleshooting investigation and advisory service would be of great benefit to the feed industry.

Revisions are presently being planned in the codes of practice for testing vegetable ingredients. If well drafted these should help reduce the problem of contaminated ingredients, provided the testing methods used are of adequate sensitivity.

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SCRAPIE

THE USE OF GENE PROBES IN THE STUDY OF SUSCEPTIBILITY TO NATURAL SCRAPIE

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Farmers facing an outbreak of scrapie in their sheep flocks often remark that the disease was "brought in" by a recently purchased ram. Such anecdotal evidence is difficult to substantiate, especially as scrapie has such stigma attached to it that true incidence figures have been difficult to obtain. It is probably a much more common disease than would seem from official diagnosis figures (Chatelain et al., 1983; Morgan et al., 1990; Hunter et al., 1991).

The lack of a preclinical diagnostic test means that sheep incubating scrapie cannot be identified until they develop symptoms and there is no way short of direct experimental challenge to predict how an animal will respond to scrapie.

EXPERIMENTAL SCRAPIE

Early experimental studies of transmission of scrapie using sheep often gave contradictory results. One such study was described by WS Gordon in 1966. Twenty four different breeds of sheep were injected intracerebrally (ic) with the source of scrapie known as SSBP/1 (described by Dickinson, 1976) and the animals were observed for two years. The number developing scrapie ranged from Herdwicks at 78% susceptible to Dorset Downs which were all apparently resistant. Later work gave different results with Herdwicks at 30% susceptible (Pattison, 1966) and indeed some of the original Dorset Downs did eventually develop SSBP/1 scrapie at much later dates (Dickinson, 1976). It became clear that there was as much variation in the "take" of scrapie inoculation between different flocks of the same breed as there was between different breeds (Nussbaum et al., 1975).

The NPU Cheviot flock

There was clearly a need to develop lines of sheep with more predictable response to induced scrapie in order to understand the progression of the disease. As a result, a Cheviot flock (at the Institute for Animal Health, Neuropathogenesis Unit (NPU),

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Edinburgh) was started in 1961 from a foundation flock of 303 ewes and 15 rams with no record of exposure to scrapie. They were split into two lines (positive and negative) on the basis of their response to subcutaneous (sc) injection with SSBP/1 (Dickinson et al., 1968; Dickinson, 1976) and a policy of careful recording was adopted to minimise inbreeding. The positive line develop scrapie in around 300 days whereas the negative line survive a natural lifespan. Negative line sheep are not believed to be truly resistant as they can contract scrapie in around 1000 days following ic injection. Positive line sheep die with 200 days of ic injection of SSBP/1 (Table 1).

Table 1 Incubation periods of SSBP/1 and CH1641 scrapie in Cheviot sheep of differing Sip genotype

Source of scrapie	Route of injection	Incubation period (days +/- SEM)	
		Positive line (Sip sAsA or sApA)	Negative line (Sip pApA)
SSBP/1	ic[a]	197 +/- 7	917 +/- 90
	sc[b]	313 +/- 9	SURVIVE
CH1641	ic	595 +/- 122	360 +/- 15

[a] intracerebral; [b] subcutaneous.

The Sip gene: From line-cross and back-cross segregation experiments it became clear that a single gene (known as Sip) controls susceptibility to SSBP/1. Sip has two alleles, sA and pA (Dickinson & Outram, 1988). The negative line are all Sip pApA. The positive line are either Sip sAsA or Sip sApA as sA is partially dominant (Foster & Hunter, 1991). Isolates of scrapie can be classified according to their relative effects on sheep of the different Sip genotypes. Most isolates (A group) produce the disease in carriers of the sA allele faster than in Sip pApA sheep, but with at least one isolate (CH1641) (C group - Foster & Dickinson, 1988a), the ranking is not clear cut and may even be reversed (Table 1).

NATURAL SCRAPIE

What relevance do these experimentally derived lines of sheep have to the natural disease? The sheep themselves are extremely useful in transmission and molecular genetic studies because their response to challenge is known in advance. They may also prove useful in studies of natural scrapie as the gene Sip, which controls incubation period of experimental scrapie in the Cheviots, is thought to affect the host response to natural

scrapie as well (although sA is thought to be recessive in this case). Crossbreeding experiments described by Foster & Dickinson (1988b) involved negative line Cheviots (Sip pApA) and Suffolks from a flock bred for high incidence of natural scrapie (Dickinson et al., 1974). Progeny were observed for development of scrapie both naturally and following experimental challenge. The incidence of scrapie was close to the expected ratio for the segregation of a single gene with one dominant allele and gave good evidence that the Sip gene affects the host response to both experimental and natural scrapie in these two breeds of sheep.

The PrP gene

The NPU Cheviot sheep have provided what may be the first reliable *in vitro* marker for susceptibility differences - restriction fragment length polymorphisms (RFLP) of the sheep PrP gene.

PrP is a protein whose gene is found in most mammals (Westaway & Prusiner, 1986). It was discovered first in the form of scrapie-associated fibrils (SAF) (Mertz et al., 1981) which accumulate in brain tissue of animals and man affected by all scrapie-like diseases. This infection specific form of a normal neuronal membrane protein is closely associated with infectivity and has been shown in transgenic experiments to have a major influence on incubation period of disease. It is thought that it may be the protein product of the gene which controls incubation period ie the Sip gene in sheep. This is not yet certain however (Westaway et al., 1991).

PrP gene RFLPs in the NPU Cheviot flock

In previous studies, we have described restriction fragment length polymorphisms (RFLP) of the sheep PrP gene in the (NPU) Cheviot flock (Hunter et al., 1989, Foster & Hunter, 1991) apparently associated with differing susceptibility to experimental scrapie ie with the alleles (sA and pA) of the Sip gene which is also thought to control response to natural scrapie (Foster & Dickinson, 1988b). The sheep PrP gene polymorphic restriction sites and fragments are as follows:- EcoRI [which gives PrP gene fragments of 6.8kb (e1), 5.2kb (e2) and 4.0kb (e3)] and HindIII [which gives fragments of 5.0kb (h1) and 3.4kb (h2)].

In NPU Cheviot sheep, fragments e1 and h2 are associated with relative susceptibility to SSBP/1 scrapie (Sip sA) and fragments e3 and h1 with relative resistance (Sip pA) (Hunter et al., 1989; Foster & Hunter, 1991). Any association of the EcoRI fragment e2 with scrapie response has not yet been assigned.

PrP gene RFLPs in sheep affected by natural scrapie

Between July 1988 and February 1991 a total of 167 naturally infected scrapie sheep were tested for the presence of the PrP gene polymorphic fragments found in NPU Cheviots. Sheep blood and liver samples were obtained from suspected scrapie affected sheep from Veterinary Investigation Centres (VIC) in various parts of Britain. Clinical diagnoses of scrapie were confirmed by histopathology (carried out by the relevant VIC) and only confirmed scrapie cases were included.

No single breed predominated - there were 32 breeds and crossbreeds (representing both British and continental sheep breeds) plus 4 sheep of unknown breed. These are listed in Table 2 with the country of origin of the sheep.

Table 2 Breeds and sources of sheep affected by natural scrapie and analysed for PrP gene polymorphisms.

Breed of sheep	Number	Source
Berichon du cher	1	England
Blackface cross	1	Scotland
Bleu de maine	18	Scotland (3)
		England (14)
		Wales (1)
Bleu de maine x Welsh Mountain	1	Wales
Bleu de maine x Whiteface Dorset	1	England
Charollais	6	Scotland (2)
		England (4)
Cheviot	9	Scotland (7)
		England (2)
Cheviot x Border Leicester	13	Scotland (11)
		England (2)
Dartmoor	1	England
Dorset	9	Scotland (2)
		England (6)
		Wales (1)
Dorset cross	1	England
Finn Dorset	1	Scotland
Hampshire	1	England
Greyface	5	Scotland
Greyface x Swaledale	1	Scotland
Jacob	1	England
Masham	6	Scotland (3)
		England (3)

(continues over page)

Table 2 (continued)

Mule	19	Scotland (2) England (17))
Rouge de l'ouest	2	England
Shetland	7	Scotland (5) England (2)
Shetland x Cheviot	2	Scotland
Shropshire	2	England
Speckleface	1	Wales
Suffolk	15	Scotland (5) England (4) Wales (6)
Suffolk cross	4	Scotland (1) England (3)
Swaledale	21	England
Swaledale cross	2	England
Texel	6	England (5) Wales (1)
Vendeen	1	England
Welsh Halfbreed	1	Wales
Welsh Mountain	3	England (1) Wales (2)
Welsh cross	1	England
Unknown breed	4	Scotland (3) England (1)

All information on breeds and ages of sheep was supplied by the VICs. For 9 sheep, the age was unknown. The average age was 3.3 years (ranging from 1.2 - 8 years) which agrees well with previously published studies of the age-specific incidence of scrapie (Dickinson et al., 1964).

PrP gene RFLP genotype analysis was carried out on DNA samples from all these sheep using the restriction enzyme EcoRI. Most, but not all of the animals were also analysed with HindIII and the results are presented in Table 3. The Southern analysis was performed using standard techniques and is described in detail in Hunter et al. (1991).

PrP EcoRI genotypes: With EcoRI, approximately 59% (99) of 167 animals were PrP e1e1, 10% (16) were PrP e3e3 and 28% (47) were PrP e1e3. The other five animals (5%) carried e2 (Table 3a). Therefore in this survey 88% of scrapie sheep carried PrP e1, the fragment associated with high susceptibility to experimental scrapie in NPU Cheviot sheep. The RFLP type frequencies were approximately e1: 74%, e2: 2%, and e3: 24%

Table 3 PrP gene RFLP genotypes of sheep in natural scrapie surveys.

a) EcoRI genotypes

	e1e1	e1e2	e1e3	e2e2	e2e3	e3e3	Total
numbers	99	1	47	2	2	16	167
Fr[a] (%)	59	0.5	28	1	1	10	

b) HindIII genotypes

	h1h1	h1h2	h2h2	Total
numbers	33	51	29	113
Fr[a] (%)	29	45	26	

[a] Fr - Frequency (percentage)

PrP HindIII genotypes: With HindIII, there were approximately equal frequencies of fragments h1 and h2 in the scrapie sheep (Table 3b). The PrP genotype percentage frequencies were h1h1:h1h2:h2h2 - 29:45:22 and as these ratios are not significantly different from 1:2:1, this may be an indication that the HindIII polymorphism, while being successful at marking differences in susceptibility to scrapie in NPU Cheviots, is not of general application.

Age of sheep and PrP genotypes: When age of sheep was compared with genotype (Table 4) there was a slight tendency for PrP e3e3 and PrP h1h1 sheep to be older than the others but this difference is not significant. As the age ranges show, both young and old sheep are represented in each of the major genotype groups.

Table 4 PrP gene RFLP genotypes compared with age of sheep affected by natural scrapie.

Genotype	n[a]	Average age (years)	Age range
a) EcoRI			
e1e1	93	3.3	(1.2 - 8.0)
e1e2	1	3.0	
e1e3	44	3.4	(1.5 - 6.0)
e2e2	2	3.3 + 3.3	
e2e3	2	4.0 + 6.0	
e3e3	16	3.8	(2.2 - 5.6)
(Total)	(158)		
b) HindIII			
h1h1	33	3.5	(1.2 - 6.0)
h1h2	47	3.1	(1.9 - 6.6)
h2h2	26	3.1	(1.5 - 7.0)
(Total)	(106)		

[a]n - numbers of each genotype for which age is known.

DISCUSSION AND CONCLUSIONS

In this study of 167 sheep affected by natural scrapie from all over Britain, we have tested the idea that RFLPs of the sheep PrP gene, which are linked to experimental scrapie susceptibility differences in NPU Cheviot sheep, can also be used to predict which sheep will be susceptible to the natural disease. The term "susceptible" is used here to indicate the probablility of developing scrapie symptoms and implies nothing about the ability of the animal to replicate scrapie without visible symptoms.

In the Cheviot sheep, response to SSBP/1 scrapie is controlled by the gene Sip (Dickinson & Outram, 1988) with two alleles, sA (partially dominant, Foster & Hunter, 1991) and pA. Our data indicates that the EcoRI fragment e1, which is associated with susceptibility (or the sA allele of Sip) to experimental scrapie in NPU Cheviot sheep is found in around 88% natural scrapie cases either as homozygote or heterozygote.

Although in NPU Cheviots the HindIII PrP fragment h2 is associated with relative susceptiblity to experimental scrapie, this RFLP did not seem so informative in the other breeds affected by natural scrapie. However comparison with frequencies in unaffected sheep groups suggest that h2 is relatively uncommon

(Hunter, unpublished observations) and so there may be some association with susceptibility which is not so strong as with EcoRI.

Combining the two RFLPs into a haplotype for each animal is difficult as each of the fragments e1, e2 and e3 have been found incombination with each of the fragments h1 and h2. However it is clear that the EcoRI polymorphism has the greatest general association with incidence of disease so far.

Comparison with healthy unaffected animals has shown that PrP e1e1 sheep, which form around 59% of scrapie cases in the survey reported here, appear to be relatively rare in healthy sheep populations (Hunter et al., 1991; Hunter, unpublished observations). Only in two groups of Shetland sheep has the frequency of e1e1 been found to be above 10%; the mean was less than 15% in 5 groups totalling over 200 sheep (Hunter et al., 1991).

PrP e3e3 sheep

If PrP e1 is linked to Sip sA, what then is the significance of the cases (around 10%) which are e3e3 and possibly therefore Sip pApA? This genotype in NPU Cheviots has relative resistance to experimental scrapie inoculation but may succumb to an intracerbral inoculation of SSBP/1 with a very long incubation period. The age of naturally infected e3e3 sheep is not significantly higher than the e1 carriers (Table 3) so a longer incubation period in these animals looks unlikely.

There may be breed differences in sheep PrP genes and polymorphisms within the sheep PrP protein coding region have been found in Suffolk sheep and NPU Cheviots (Goldmann et al., 1990 and 1991) and these may result in a more definitive test. Another possibility is that the e3e3 sheep are contracting a different type of scrapie. We already have experimental evidence for this in the scrapie source CH1641 which can give shorter ic incubation periods in Sip pApA Cheviots than in Sip sA carriers (360 +/- 15 days and 595 +/- 122 days respectively, Foster & Dickinson, 1988a) and this possibility is now under investigation.

Given that there is no way of knowing anything about the type of scrapie affecting the sheep or indeed the dose or route of infection, we can conclude that there is a good association of the sheep PrP gene EcoRI fragment (e1) with appearance of natural scrapie in sheep of a wide range of breeds. However the use of such a test to breed scrapie "resistant" flocks requires caution (Hunter et al., 1989). Such animals may carry a hidden infection or may even succumb to an unusual scrapie strain. Much more knowledge is needed about both the PrP and Sip genes before regarding the apparent genetic linkage as a fool-proof indicator

of a sheep's response to challenge with scrapie. All field strains of scrapie may not be the same as can be seen from the quite different responses of the Cheviot lines to SSBP/1 and CH1641 (Table 1). An animal with low susceptibility to one type of scrapie may well develop disease when exposed to a different type by, for example, being sold into an area with a different endemic strain. However high incidence outbreaks may be prevented by maintaining a mixture of PrP genotypes within the flock.

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DETERMINING THE PREVALENCE OF SCRAPIE IN SHEEP AND GOATS IN THE UK: THE CONFLICTS OF SPEED, SIGNIFICANCE, ACCURACY, BIAS AND DOING NOTHING

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In April 1988, I published a speculative article suggesting that Bovine Spongiform Encephalopathy (BSE) was derived from scrapie infected meat and bone meal (Morgan 1988) One possible contributing factor to the sudden appearance of the disease was that the prevalence of scrapie had increased to a point where the minimal infectious oral dose of the scrapie agent for cattle had been exceeded. At the time there was no objective information on the prevalence of scrapie in the UK in spite of its presence in the national flock for over 200 years. Opinions varied as to the prevalence of disease. Recent text books suggested that "the disease had largely disappeared" (Blood, Radostits and Henderson 1983). The number of cases diagnosed at Veterinary Investigation Centres was also low but in the author's experience scrapie seemed to be not only a common nervous disease of sheep but also a disease of great concern to sheep farmers.

At the time of the study, attention was focused on BSE in cattle. Research funding for scrapie was being reduced and there was a danger that even in the presence of BSE, scrapie in sheep would be ignored. It seemed important to gather information on the prevalence of scrapie for two major reasons. To support the hypothesis that BSE was derived from scrapie and to provide epidemiological evidence on which priorities for research and control could be formulated.

In setting out to determine the prevalence of scrapie, the three most important criteria were accuracy, speed, and cost.

We began by attempting to design the "Rolls Royce" study. A 2-3 year study of a random sample of British sheep farmers stratified by region, with clinical, post-mortem and histological examination of the brains of all dead and cull adult sheep and a proportion of lambs at slaughter was considered. We estimated that this study would involve about 2000 farmers and (assuming a 20% replacement rate) 40,000 sheep. There would also be a dependence on flock owners to notify us of all sick, dead and cull animals. Brain removal and fixation would also have to be carried out within 24 hours. This was impractical even with major grant funding and consideration was given to a postal questionnaire survey.

The two major problems envisaged in conducting a postal survey were a poor reponse rate and the method of case ascertainment. In view of the sensitive nature of the disease a poor response rate was not only likely to occur but also to introduce systematic bias. Anonymity was considered as a method of improving the

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response but this would preclude testing the non-responders and the use of personal reminders.

The method of case ascertainment was a more serious problem. VIDA records suggested that the proportion of farms in the sample with a confirmed histological diagnosis of disease would be small. The use of clinical signs as a method of diagnosis was then considered.

In advanced cases, the clinical signs of scrapie - scratching, weight loss, and incoordination are easily recognisable. However, the signs are often insidious in onset with mild changes in behaviour and gait being early signs of the disease. There were three essential questions. Would sheep farmers recognise clinical cases of scrapie ? What was the sensitivity and specificity of clinical signs as a method of scrapie diagnosis ? Would the use of farmer reported clinical signs introduce systematic bias into the study ?

In clinical contact with sheep farmers, the author had been impressed by the stage at which these sheep farmers who had experienced scrapie in their flocks could recognise early clinical cases. No information on sensitivity and specificity was available but the author considered that this information might become available or be determined after the study. The use of clinical signs was considered to be the only practical method of case ascertainment. Loss of accuracy of diagnosis is a common feature of large scale surveys but has not prevented them being carried out. In many cases it introduces random error which cancels itself out. Of more importance is systematic error. In this case, our concern was that owners who had not seen scrapie in their flocks would not know the clinical signs and would not recognise the disease.

A postal questionnaire was considered but a major reservation was that a poor response rate would not justify the marginal cost (approx £1000) of the survey. Interview questionnaires are known to result in a higher response rate but a national interview based survey was considered impractical.

Fortuitously, a national, biennial sheep exhibition was planned for August 1988 and the possibility of collecting information at this event was considered. A major concern was the method of sampling, the sample size and the relationship between the study population, (attendants at a major national exhibition) and the target population (British sheep farmers). Systematic sampling was considered but a problem envisaged in this, given that once admitted to the exhibition, people remained for most of the day, was that some individuals might be approached more than once and that, given the labour available, the sample size would be small. In the end a decision was made to collect as many questionnaires as time and labour would allow

The author had previous experience of collecting information at a National Hill Event in 1986 using a 4 page questionnaire. This pilot study had indicated that flock owners would complete a questionnaire provided that it was short.

A questionnaire was designed to gather the following information:- The proportion of farms with scrapie affected sheep and the proportion of sheep developing scrapie each year. Other important considerations were that the questionnaire should be short, anonymous, self explanatory, should not look for breed differences and should contain questions which would allow the accuracy of self diagnosis of scrapie to be tested. The questionnaire was pretested on flock owners working at the Veterinary School and is its final form is shown in Fig.1.

A list of clinical signs was included as a quality control for self diagnosis and to allow the identification of clinical signs by farmers with and without scrapie affected sheep to be compared, i.e. to attempt to identify and quantify sytematic bias in case ascertainment.

The clinical signs of scrapie used were NERVOUSNESS, WEIGHT LOSS, ITCHING, and INCOORDINATION. Selecting signs which were not typical of scrapie was more difficult. Locomotor disturbances and alopecia may occur with scrapie. The signs needed to be easily observed. Eventually DIARRHOEA and COUGHING were the only clinical signs which we felt were clearly distinct from those which might be seen in scrapie. The questionnaire took around 90 seconds to complete.

In planning the execution of the study, we decided that exhibition attendants would be given the questionnaire on a clip board, allowed to complete it in private and to "post" it into polling boxes to ensure anonymity. We calculated that with 2-3 people operating 8 clip boards we could, in theory, collect about 2,000 questionnaires.

The survey was conducted from a fixed site inside a building housing technical and educational exhibits.

During the exhibition the British Sheep Dairying Association offered to distribute our questionnaire to its 300 members in the Summer newsletter. The questionnaire used in this postal survey was identical to that of the exhibition survey with the exception that an address, fold lines and stamp were added to the reverse side.

Response: We estimated that 9,600 sheep farmers attended the exhibition; 295 completed questionnaires and 279 were suitable for analysis. Of the 300 members of the BSDA, we estimated, from a random telephone of survey of 40 of them that 210 kept milking sheep. 89 returned completed questionnaires giving a response rate of 42%.

Prevalence: 34% (96/279) (95% C.I. 28-40) of respondents at the exhibition survey and 17% (15/88) (95% C.I. 13-21%)) of BDSA members indicated that they had seen sheep in their flocks with the clinical signs associated with scrapie.

Incidence: There was considerable variation in the reported incidence of scrapie in affected flocks ranging from 0.04-10 cases/100 sheep/year. The mean was 1/100/year for the exhibition survey and 0.5/100/year for the BSDA survey.

Diagnosis: Scrapie was diagnosed in this study on the basis of clinical signs. This was a major disadvantage of the study as the "gold standard" for diagnosis is histology. However, the results suggest that the accuracy of diagnosis was high. Half (Exhibition 49%; BSDA 53%) the respondents indicated that diagnosis had been made by a veterinarian, veterinary investigation laboratory or a combination of these. Of the respondents who had made the diagnosis themselves, (Exhibition 39%; BSDA 47%) over 70% (Exhibition 78%; BSDA 86%) selected three or more of the 4 correct clinical signs from a list of 6. Over 90% selected two or more of the correct clinical signs. Only 1% of farmers selected the two incorrect signs.

Geographical distribution: Scrapie was identified in 35/47 counties in England and Wales. The sample size was too small to investigate differences in prevalence between county.

Conclusions: This study provided the first information on the prevalence of scrapie in sheep flocks in the U.K. the authors were aware of the deficiencies in

sample selection, non-response bias, accuracy of diagnosis and small sample size, but felt it important in view of the occurrence of BSE that this information was published (Morgan et al 1990). We suggested that analytical epidemiology could complement molecular biology in understanding the nature of scrapie but that the only accurate way to do this was to make the disease notifiable.

The study drew immediate criticism from veterinarians (Martin 1990) and the sheep industry who feared damage to exports. Unfortunately the article was also widely misreported by the press, suggesting that 30% of all sheep in the U.K. had scrapie. MLC figures on lamb exportation indicate that neither have had a dramatic long term effect on lamb exports.

FOLLOW UP STUDIES

The exhibition survey was repeated in 1990. We also carried out a postal survey of 2,500 members of the British Goat Society using a similar questionnaire modified for goats. No information on the prevalence of scrapie in goats was available at the time.

Response: 1112 people were approached at the exhibition. 777 questionnaires were suitable for analysis giving a response rate of 72%. Of the remainder, 271 had no sheep, 41 refused to take part and 23 were unsuitable for analysis.

2,295 questionnaires were sent to members of the British Goat Society in the August edition of their journal. Two reminders were published in subsequent editions. The response rate was a disappointing 37%. 843 questionnaires were returned and 823 were suitable for analysis.

Demographic details: A total of 315,319 sheep and 8,885 goats were represented in this study. Flock size ranged for 1-5,000 for sheep and 1-390 for goats. When compared with the national flock census there was concordance in the frequency distribution of flock size. All the counties were represented in the goat survey. In the sheep survey 41/46 English counties, 7/9 Scottish counties, 2/4 N.irish counties and all the Welsh counties were represented. The regional distribution of sheep in this study differed from that of the nationa flock. Scotland, N.Ireland and Northern regions were under-represented whereas the South West, Midlands and South East were over-represented. This reflected the location of the Exhibition in the South of the country.

Prevalence: 26% (198/777) (95% CI 24-28) of respondents in the exhibition survey indicated that they had seen sheep with clinical signs of scrapie in their flocks.

The prevalence in the BGS survey was much lower. 2.4% (20/823) (95% C.I. 1.9-2.9). of respondents indicated that they had seen goats with clinical signs of scrapie in their flocks.

Incidence: The incidence in affected flocks ranged from 0.03-7.5 cases/100 sheep/year. The mean was 1.0 case/100 sheep/year. The incidence in affected goat herds ranged from 2-50 cases/100 goats/year, reflecting the small flock size of many of the respondents. The mean incidence was 14 cases/100 goats/year. When means were calculated with the total number of cases as the numerator and the total number of animals in affected populations as the denominator the means were 0.4 cases/100 sheep/year and 0.6 cases/100 goats/year.

Interestingly the incidence of scrapie in the total population of both sheep and goats was 0.1 case/100/year.

CONCLUSIONS

This is the first quantitative information on the prevalence of scrapie in the U.K. It suggests that scrapie is widespread in sheep flocks but importantly that a large number of flocks appear free of clinical disease. This provides corroborating evidence for the hypothesis that BSE was transmitted to cattle by the oral route. The study also suggests that there has been little change in prevalence of scrapie during the current BSE epidemic. The prevalence of scrapie in goat herds was much lower. This may reflect a true difference in these populations. However, it may also be an effect of population size. Goat herds were considerably smaller than sheep flocks. Scrapie affected populations were significantly larger than non-affected groups populations.

An interesting finding was that the incidence of disease in the total population was similar for sheep and goats. This was 1 case/1000 animals/year. A feature of naturally occurring spongiform encephalopathies is that they maintain themsleves at low prevalence in affected populations. Is it possible that in the absence of control measures this has occurred in sheep and goats?

We have much to learn about the natural disease of scrapie in sheep. Epidemiological studies will complement research in molecular biology and genetics in our understanding of the disease. We have argued that the disease be made notifiable in order to allow effective epidemiological studies to be undertaken (Morgan et al 1990). Scrapie will become notifiable later this year. It is important that we adopt a positive attitude to this development at national and local level and that effective epidemiological studies are undertaken. It is also important that attempts are made to maintain the status of the large number of flocks in the U.K. that are free of clinical diseases. Doing nothing is not a strategy for preventive medicine.

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A SCRAPIE SURVEY BY POSTAL QUESTIONNAIRE: AIMS, PROBLEMS AND RESULTS

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Scrapie was first documented in sheep in England around 1730 (Comber, 1772), and has been recorded in many other countries (Stockman, 1913, Hlidar, 1937, Zlotnik & Katiyar, 1961, Mizoi et al, 1984). However, particularly in Great Britain, few epidemiological studies of the naturally occurring disease in sheep have been undertaken, although Parry (1960, 1983) and Morgan and colleagues (1990) have done some work in the field. The secrecy surrounding the disease (M'Fadyean, 1918; Morgan et al, 1990) and the pre-mortem diagnostic difficulties (Fraser et al, 1989, Ikegami et al, 1991) have resulted in attention being focussed on laboratory models, particularly rodents.

The occurrence of bovine spongiform encephalopathy (BSE) in cattle (Wells et al, 1987) stimulated interest in natural scrapie, since this appeared to be the most likely source of the disease (Wilesmith et al, 1988). To address the dearth of information on the epidemiology of natural scrapie, a preliminary study, utilizing a postal questionnaire, was designed with the following objectives:

- To obtain basic descriptive epidemiological features of sheep scrapie, for example, within-flock incidence, age specific incidence, breeds affected, incidence by flock size, and to investigate any changes over time.
- To investigate potential means of introduction of infection into sheep flocks, particularly purchased animals and feed supplies.
- To investigate the potential biases of submissions to veterinary investigation centre's (VIC's) when compared to clinical diagnoses.
- To assess the availability of data on sheep scrapie, particularly in view of the secrecy often surrounding it, to assist in the design of future studies and the assessment of biases in any such studies.

MATERIALS AND METHODS

Selection of Farms in the Study

Farms were selected by retrieval of the unique diagnostic case reference numbers of pathologically confirmed cases of scrapie from 1980 onward from the VIDA database, a record of all diagnoses made at VIC's and maintained at the CVL. Each VIC was then asked for the name of the referring veterinary surgeon (VS), and farm of origin, for up to 25 recent cases. Of the 27 VIC's approached, 25 replied. The referring VS was asked to make the first approach; a

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questionnaire was sent to all farmers who agreed to participate and also to a small number whose VS had said they would be likely to participate without prior contact.

Case Definition

Two case definitions have been used in this survey. The first, 'VIC cases', are those suspect cases of scrapie confirmed by histopathological examination of the brain. The second, 'non-VIC cases', are any other cases of scrapie diagnosed only on clinical signs, either by the VS or farmer. In the analyses, 'all cases' refers to VIC plus non-VIC cases.

Questionnaire Design

A prototype questionnaire was developed with help from farmers and MAFF staff, of which 100 were distributed, with an explanatory covering letter and stamped addressed envelope for return. The period covered by the survey was 1980 to 1990 inclusive. The farmer's name, address and survey reference number were entered before despatch. As it became apparent that several sections caused completion problems the design was extensively modified. One general change was that references to years were altered to lambing seasons, Eg 1980 = lambing season 1980-81. A summary is given in table 1.

Table 1. Summary of questions on the prototype and the modified questionnaires

Information Requested	Prototype	Modified
Type of farm; hill, upland or lowland	Yes	Yes
General farm management details	No	Yes
Sheep population on the farm, estimated if necessary (to be indicated by E).	Yes; for 1980 1985 & 1990 by age in years.	Yes; over 1 year old only; by sex for all years; by age for 1990.
Culling & replacement policy	No	Yes
Breeds present.	Yes; by year and sex.	Yes; by sex & year; by no in 1990-91.
Sources of all stock	Yes; in detail.	Yes; briefly.
Feeding regimes.	Yes; in detail.	Yes; in detail but layout & groups altered.
Cases of scrapie, totals to be estimated if necessary (to be indicated by E).	Yes; by year, age, sex, breed and source.	Yes; in more detail, Eg. diagnostic method.
Clinical signs of scrapie.	No	Yes

Follow-up for Non-Responders

Non-responders were sent a letter after one month, stressing the importance and confidentiality of the survey. 22 (10%) of non-responders were randomly selected, and telephone contact attempted to ask whether the form had been received, why it had not been completed, what size was the flock in 1990 (excluding 1990's lambs), and how many cases of scrapie had been seen over the survey period.

Data Recording

All the survey results were entered onto a Prime 4450 mini-computer using the software package Prime Information, and specific programmes were written for data entry and analysis. Validation of data files was by further programmes and visual scrutiny.

National Sheep Flock

Data was taken from figures obtained from the national agricultural census conducted in June each year.

Methods of Analysis

Wherever possible, information from both types of questionnaire was amalgamated. On the original design, population data was available only for 1980, 1985, and 1990 and extrapolated for intervening years. Some information was available only from one form type. Analyses for comparison of proportions and examination for trends was performed using 'Statcalc' in 'Epi-info Version 5'.

RESULTS

Response Rate

407 questionnaires were despatched, of which 100 (24.57%) were the prototype, used from June until December 5th, 1990, and 307 (75.43%) were modified forms, used until July 10th 1991. Overall, 167 (41.03%) were returned with useful information, 16 (3.93%) were returned blank, and 224 (55.04%) were not returned by 5th August, 1991. Of the prototype, 41 (41.00%) gave useful information, and for the modified design 126 (41.04%) gave useful information. There was no marked geographical bias between responders and non-responders.

Telephone contact with 12 of the non-responders gave reasons for non-completion as follows (one gave two reasons):-

Lack of time (5 of 12); 2 said they would complete it soon.
Mislaid the form (1 of 12); but she found it as we spoke.
Not interested (1 of 12).
Never received form (2 of 12); and one added 'too long anyway!'
Incomplete records made completion difficult (2 of 12).
Lazy (1 of 12).
Disagreed with VIC diagnosis of scrapie (1 of 12).

For these 12 non-responders, flock sizes ranged from 28 to 1000 sheep, the average being 336. 127 scrapie cases were estimated over the survey period; roughly 1 case per farm per year or 0.3 cases per 100 sheep per year.

Farms and Flocks

Of the 167 farms from which responses were received lowland farms accounted for 79 (47.3%), hill farms 31 (18.6%) and upland farms 34 (20.4%). 23 (13.8%) were of unknown type. Results for additional questions on the modified form were as follows. Acreage was given for 106 (84.1%) of the farms; of these 4 (3.8%) were less than 10 acres, and 16 (15.1%) were 1000 or more acres. Recording systems were in use at 56 (44.4%) of farms, and not in use at 50 (39.7%) with no information for 20 (15.9%). 60 (47.6%) utilized mixed grazing with other farms, and 46 (36.5%) did not; again for 20 (15.9%), no information was available.

The number of different breeds and cross-breeds recorded increased from 69 in 1980 to 161 in 1990; especially marked was the proliferation of new crosses. For example Bleu de Maine was first mentioned on one farm in 1984. By 1990 it was recorded as purebred or cross (9 types) on 20 different farms. The numbers of different counties from which flocks came increased from 33 to 44 over the same period. Ascertainment of the proportion of males was difficult; the relevant sections were often poorly completed. In 1989, for animals over 1 year old, for the 87 farms where a figure could be calculated, the range was wide, from zero to 29.4%; the modal value was 2.5%, occurring on eight farms. Also for animals over 1 year, national census data gives an overall percentage of 2.3% males both for 1989 and 1990.

Scrapie Cases

Totals cases by case definition: A total of 1925 total cases was recorded of which 204 were identified as VIC cases; for both categories numbers per year increased (fig 1). The proportion of VIC cases also increased with time, from 2.7% (3 of 113) to 15% (58 of 387); VIC cases differed in a number of ways from all cases.

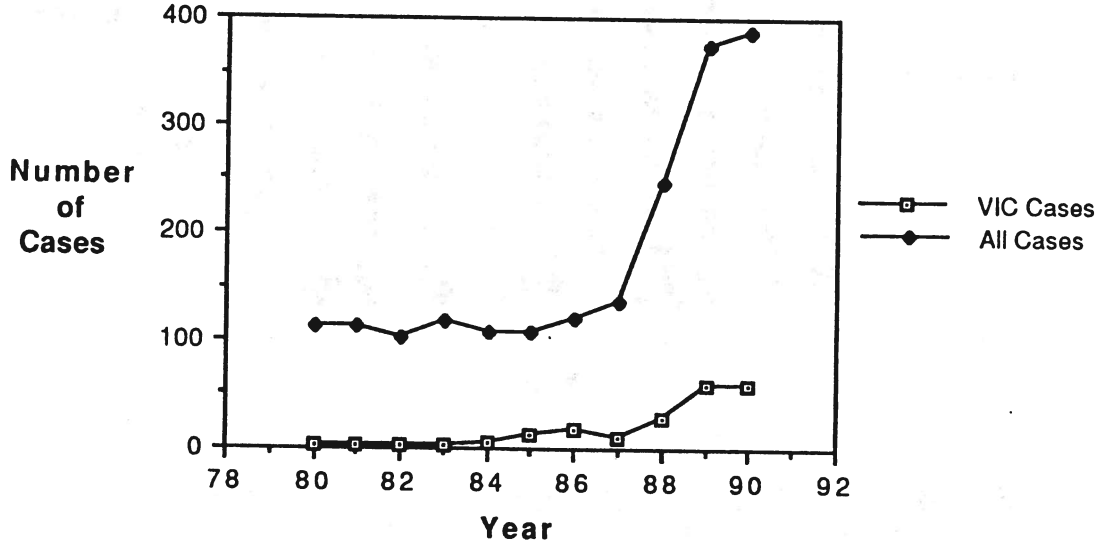

Fig. 1 Scrapie cases: Total per year

Sex: 1526 (79.3%) were female, 74 (3.8%) were male, 325 (16.9%) were of unknown sex. For VIC cases, the proportion of males was 23% (P=0.0000); only 9.1% of females were VIC cases, compared with 63.5% of males.

Age: The distribution of disease by age is shown in fig. 2. The majority were between 2 and 4 years of age. The proportion of VIC cases in animals older than 4 years of age was significantly greater than in age groups 1 to 4 years (P=0.0000). There was only one case below 1 year of age, a VIC case.

Fig. 2 Total scrapie cases: Age breakdown

With respect to the age distribution over time, little overall change was apparent; the proportion of cases below 2 years of age decreased slightly, whilst those above 4 years of age increased slightly, but the proportion between 2 and 4 years of age did not significantly alter (P= 0.7716) (fig. 3).

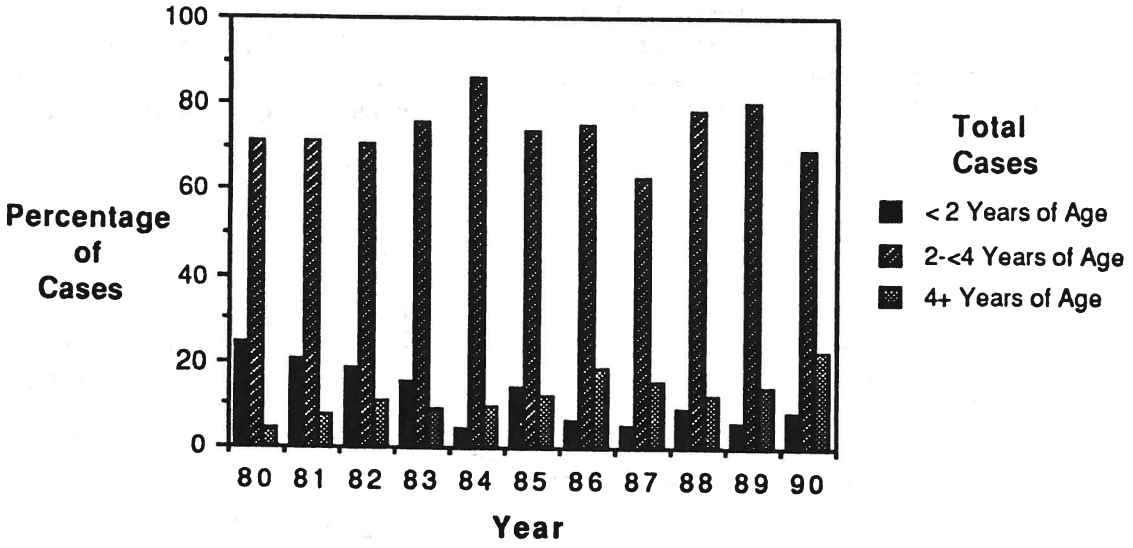

Fig. 3 Scrapie cases: Age groups, as percentages, by years

Breed and Geographical Distribution: 76 different breeds and cross breeds were recorded, with an increase from 9 in 1980 to 48 in 1990. Particularly noticeable was the increase in the proportion of foreign breeds, from none in 1980 to 12 (25%) as

either purebred or cross, by 1990. The proportion of foreign breeds which were VIC cases was greater than the proportion of all breeds which were VIC cases. The numbers of counties from which cases were reported increased from 15 in 1980 to 35 in 1990, and differences in the proportions of cases for various areas over time was apparent.

'Within-Flock' Incidence Rates

Where available, population data for the survey flocks, for animals over 1 year, was either taken from the form, or extrapolated for the intermediate years, which was necessary for approximately 20% of flocks shown in table 2. The number of known sheep increased from 31.9 thousand in 1980 to 56.8 thousand in 1990. The range of flock sizes every year was wide, but the average flock size remained steady.

Table 2. Total population of sheep (1 year or more years of age) in the survey by year and flock sizes

Year	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90
Tot. No Flocks*	74	77	83	91	95	108	113	115	118	119	133
Tot No Sheep**	31.9	33.2	36.3	39.3	40.1	43.0	46.0	48.1	51.4	50.8	56.8
Av Sheep / Flock	432	431	438	432	422	398	407	418	435	427	430
Max. Flock Size	2250	2200	2200	2200	2200	2200	2200	2466	2470	2200	2200
Min Flock Size	2	3	3	4	5	1	3	3	5	8	2

* = Total number of flocks where the population is known or can be estimated
** = Total sheep numbers given in thousands

For each year of the survey, for each farm with a known or estimated sheep population, and where one or more cases of scrapie (all cases) had occurred in that year, the incidence rate (IR) was calculated as cases/100 sheep/year. The minimum, maximum, and mean IR's for each year were calculated and the range was highly positively skewed; for this reason the annual median IR's were also calculated, and these are far more stable over time, ranging from 0.49 to 1.02 cases/100 sheep/year (table 3).

Table 3. Within-flock incidence rates (case per 100 sheep per year)

Year	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90
Flocks.Scrapie+ & Pop'n Known	15	19	21	18	23	31	33	34	52	77	77
Min IR	0.08	0.08	0.05	0.08	0.08	0.06	0.05	0.08	0.06	0.05	0.08
Max IR	4.55	7.67	8.65	33.78	66.67	6.67	10.00	7.69	14.29	25.00	50.0
Mean IR	1.61	1.58	1.68	3.08	4.07	1.22	1.41	0.96	1.30	2.50	2.15
Median IR	0.49	0.83	0.61	0.75	0.61	0.60	0.56	0.46	0.55	1.02	0.67

Comparison of the proportion of flocks with an IR below 0.99 to those with an IR of 1.00 to 2.99 showed a slight decrease in the former over time ($P=0.0384$), but there was no significant change in the overall proportion of flocks with an IR above 3.00 ($P=0.4252$). The groups were chosen in order to get a reasonable

number of flocks per group, per year (fig 4).

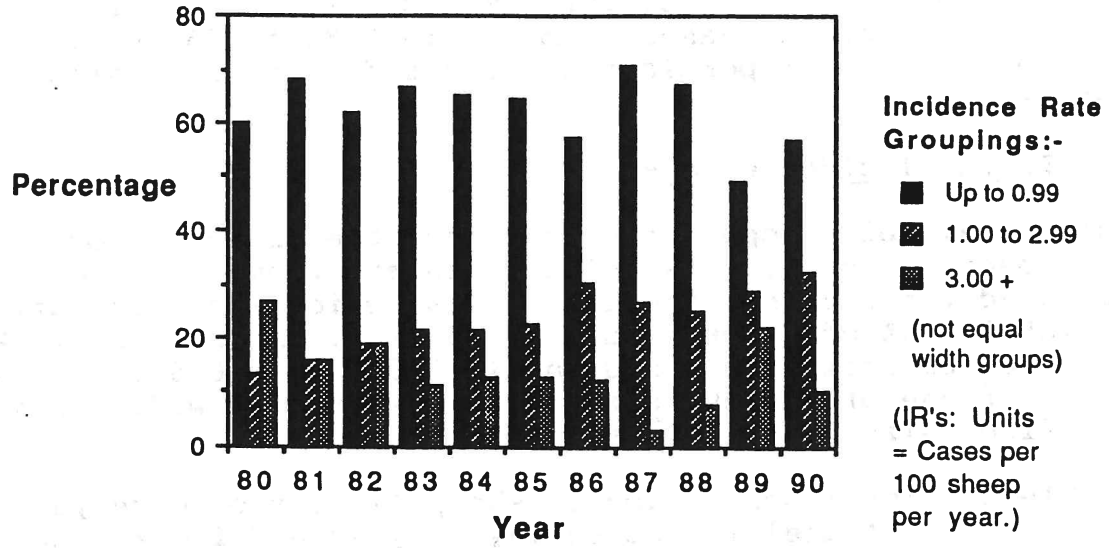

Fig. 4 Annual frequency distribution of incidence rates

Survey Flock Size; Comparison with the National Sheep Flock

Comparison of average numbers of sheep over 1 year old per holding, for survey flocks and the national flock (table 4) shows for all years the average survey holding population was about twice that of the national flock. The known percentage of the national flock in the survey increased from 0.21% in 1980 to 0.28% in 1990, whilst the national population rose from 15.5 to 20.2 million. The percentage of holdings included also increased from 0.12% to 0.21%, these also increasing nationally, from 74.6 to 80.8 thousand.

Table 4. Average holding size per year: national flock of Great Britain and survey flocks

Year	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90
Av : GB	208	212	215	217	218	219	221	230	236	242	250
Av : Survey	432	431	438	432	422	398	407	418	435	427	430

For 1990, for sheep over 1 year old, there is no significant difference (P=0.2724) between the national flock and survey flocks of known size (79.6% of 167 flocks), when comparing the proportions of holdings in the following groups; holdings with less than 50 sheep, those with 50 to 199 sheep, and those with 200+ sheep, the groups used in census data. Percentages are, for the survey flocks and national flock respectively; less than 50 sheep, 15.8% (21 flocks) and 17.5%; 200 or more sheep, 62.4% (83) and 56.1%. There may therefore be a disproportionate number of extremely large flocks in the survey thus increasing the average flock size; the original data does show a number of large flocks of around 2000 sheep.

Sources of stock

Only 2 (1.2%) of farms claimed no stock were purchased within the survey period, 142 (85.0%) had bought at least one animal and

status was undetermined for 23 (13.8%) of farms. 849 (44.1%) of total cases were homebred, 492 (22.6%) were purchased; the remainder were of unknown origin. A significantly higher proportion of purchased cases were VIC cases (109 of 204) than of all cases (492 of 1925) (P=0.0007). For females, being purchased considerably increased the likelihood of being a VIC case (P=0.0000), but for males the difference was much less pronounced (P=1.0000) (fig 5); this suggests that for females, being purchased increased the likelihood of being sent for VIC diagnosis.

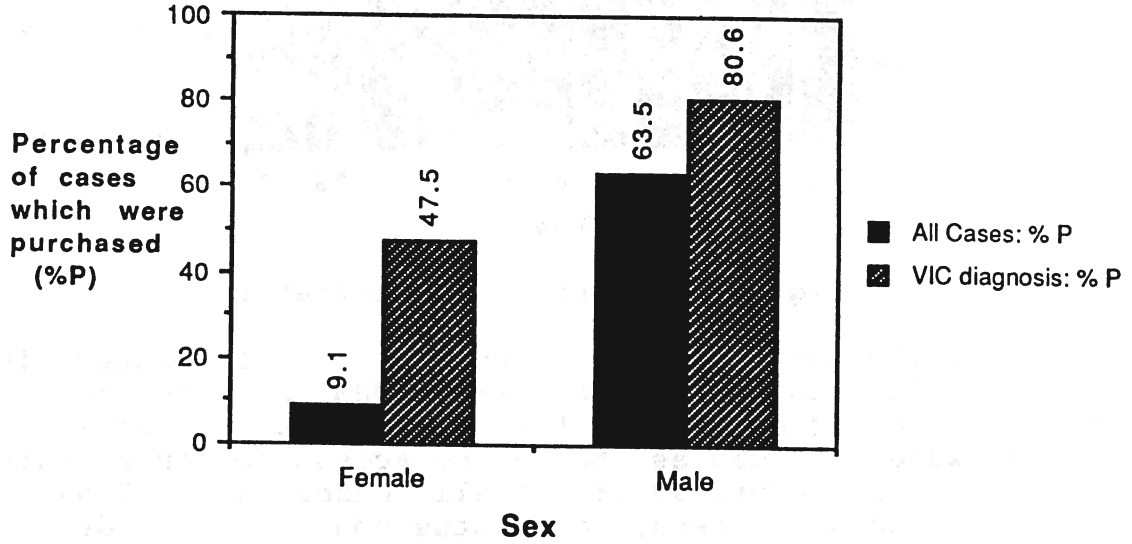

Fig. 5 Effect of source of case on likelihood of VIC diagnosis

The quality of information given meant that tracing the origin of purchased stock was not feasible during the course of this survey; many owners were either unable or unwilling to give information on the source of their stock, or asked specifically that the breeder or dealer was not contacted. Sheep from dealers or markets were often impossible to trace. On some farms, stock came from a large number of different sources. These problems were compounded by the slow rate of questionnaire return.

Stock Feeding Practices

In the assessment of the possible association between recent cases of scrapie, and exposure to ruminant derived meat and bone meal (MBM), a number of problems were encountered. Many farmers gave very incomplete information on the feeding practices, feed manufacturers and suppliers they had used since 1980. For proprietary concentrates and compounds for inclusion in home-mixes, although total protein content was given, the variation in individual ingredients was influenced by prevailing market prices and records were not always available. They were therefore all analysed together as 'concentrates'. Until July 1988 all potentially contained MBM. Only 5 farms could be positively identified as not having used concentrates during the survey period, and the proportion known to be feeding bought concentrates to any sheep remained stable, between 70% and 80% per year; also stable was the proportion of farms known to be feeding concentrates to breeding replacements under one year old, between 45% and 52% (fig 6).

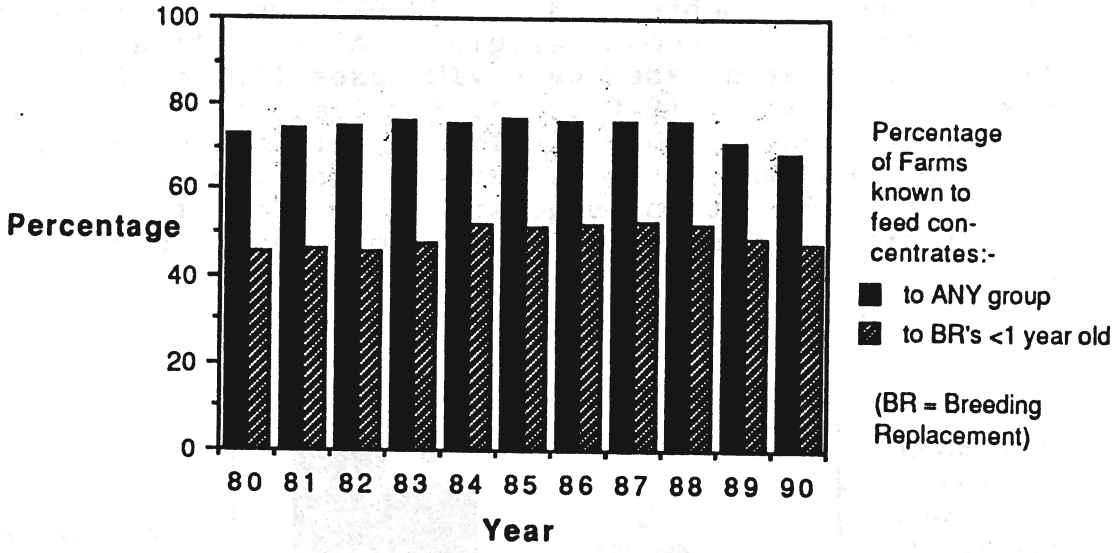

Fig. 6 Feeding of concentrates

For cases, the possibility of exposure to concentrates (which, prior to July 1988 potentially contained MBM) at some time during the animals life was high; only 5 (2.5%) VIC cases, and 11 (0.6%) total cases were recorded as having no access to concentrates at any time. The remainder, 99.4% of all cases, and 97.5% of VIC cases, either had had access, or status could not be determined. Of those 629 cases where information on exposure as a lamb was available, 599 (95.2%) had been fed such concentrates.

DISCUSSION AND CONCLUSIONS

Bias in Farm Selection

Farm selection is open to bias in two main ways. Firstly, farmers who are prepared to have a VIC examination for suspect scrapie may not be typical; factors involved include costs, the 'stigma' surrounding scrapie, the perceived importance of the disease and of the suspect animal, the clinical picture and the farmers or VS's diagnostic confidence. Secondly, at all stages of selection, co-operation from an intermediate source was necessary, a factor likely to differ both randomly, and also with a directional bias again depending upon perceived importance of the disease, perhaps related to its prevalence in the area.

Comparison of VIC cases with all cases show several differences; it is reasonable also to suggest further bias for those farms where no VIC examinations are undertaken; unfortunately no information is available on VIC negative suspects. An additional indication may be the large average size of survey flocks compared with the national figure. However, there is still much secrecy surrounding scrapie and random selection of farms may lead to false denials. VIDA selection reduces incentive to conceal the disease, and comparatively honest information with bias is preferable to answers where a large proportion may be false.

Non-Responders

In this type of survey, a 41% response rate is not considered unusually low but was disappointing as almost all had agreed to take part. A response bias was highly likely and one indication of this may be the smaller average size of the flocks of those non-responders contacted by telephone, though no firm conclusions can be drawn from such small numbers. However, the impression from the answers given is that secrecy was not an important factor in non-completion here.

Misclassification

Most cases of scrapie are probably diagnosed by farm staff. Although farms in the survey have experience of at least one case of VIC confirmed scrapie, the clinically defined cases are still liable to greater misclassification; for example, there may be a tendency to overdiagnose any CNS signs as scrapie. The section on clinical signs was included in order to partly address this question. Problems with classification of 'concentrates' have already been mentioned.

Questionnaire Completion and Interpretation

Generally, the sections on farm management, and scrapie cases were well completed, but for all other sections problems commonly recurred. Sections involving sheep numbers, either as totals, or stratified by sex or age were often poorly completed; either the information was not present, or different sections did not tally. In some cases headings had been altered to fit the information given. Rarely was there an indication that the figure was an estimate, yet that often appeared to be the case. Although altered to address these difficulties, the modified form was no more successful than the original, and the problems were thought to be due to lack of records, particularly since 1990 was comparatively well completed. Similar problems have been described with the documentation of feedstuffs, also thought to be due to lack of records, subsequently compounded by lack of manufacturers data. Again the modified form made little difference.

Questions regarding sources of stock were another problem area partly due to lack of records, but some farmers did not complete this section even when other parts were fully completed; some stated their unwillingness to give this information, and some gave it but requested that the breeder or dealer was not contacted; there was clearly an element of secrecy here. Where information was available, it was often only a market or dealer, making any further tracing very difficult, and a considerable number of farms obtained stock, and therefore possibly also disease, from very many different sources every year. For these reasons in the modified questionnaire this section was much reduced. Other problems regularly encountered involved the terminology both for different classes of stock, and different breeds and cross-breeds of sheep.

Conclusions

Investigations into the epidemiology of naturally occurring

scrapie are likely to be hampered particularly by lack of documentation kept on farms, and a degree of apathy on the part of many farmers. Telephone discussions both with non-responders and others indicated that personal contact, although more costly, would increase response rate, and improve information gathering in a lengthy questionnaire of this type. The complexity of the questionnaire appeared to cause many problems in completion, even when information was available, as evidenced by the lack of correlation, respondent-altered headings and misunderstood instructions regularly encountered. Short simple questionnaires on specific aspects may be advantageous if postal surveys have to be used.

Because of the problems encountered, results from this survey should be taken only as a guide to the scrapie situation on farms in the survey. However, the following points can be made. There have been suggestions from veterinary surgeons and farmers that recently there has been a tendency for a decrease in the typical age at diagnosis of scrapie cases. This survey presents quite strong evidence that this is not the case. However, the problems in getting age structures for flocks meant that it was not possible to calculate age specific incidences. Concern has been expressed that for infected flocks, there has been an increase in the 'within-flock' incidence with time, however there is no evidence from this survey that this is happening. Overall results for 'within-flock' IR's show stability over time; in examining this aspect of the data, the median annual IR seems to be a more appropriate statistic than the mean. The results strongly support the hypothesis that scrapie cases with a positive VIC diagnosis have significant differences from all clinically suspect cases.

In conclusion, for farms selected via the VIDA database, secrecy was not a major factor except for questions on sources of stock. However, selection bias exists, and it would be unwise to extrapolate results directly to the national sheep flock, other than as a tentative basis for further investigation.

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COMPANION ANIMAL EPIDEMIOLOGY

AN EPIDEMIOLOGICAL INVESTIGATION OF PET OWNERSHIP AND BONDING IN SOUTH CENTRAL ONTARIO, CANADA

B.E. Leslie, A.H. Meek[1] and G.F. Kawash[2]

Many personality characteristics such as dominance, nurturance, aggression (Kidd and Kidd, 1980), empathy (Levinson, 1978) and self-control (Levinson, 1978, and Hyde et al., 1983) have been reported to be influenced by bonding to a companion animal. The strongest impact on personality development is thought to occur in mid-childhood or during the pre-adolescent years, that is, nine to twelve years of age (Davis and Juhasz, 1985). However, this effect is not well understood. As such, this study was designed to further elucidate the relationship between the personality of the pre-adolescent child and his or her pet. Specifically, the objectives were to:

1. measure the strength of the bond between grade five children and their favourite pet;
2. determine a profile of personality traits for these children;
3. describe the past and present pet ownership of each child;
4. evaluate the associations between pet bonding and personality.

SAMPLE SELECTION AND DATA

The target population was grade five children in south central Ontario, Canada. For convenience reasons, a county close to Guelph was selected and its Board of Education contacted. Three hundred and fifty students were requested for the study with a distribution of 50% from urban and 50% from rural schools. The Board of Education prepared a list of eight schools whose principals agreed to have their students participate on the condition that the students receive parental consent. Schools 1 to 5 were rural and had a total of 232 students in grade five or grade five/six 'split classes'. Schools 6 to 8 were urban and had a total of 161 students.

Parents of all children in grade five or split classes were sent both a parental consent form and a letter of explanation

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regarding the research project. Only those students who returned signed consent forms were included. The study was completely anonymous so that neither the student nor his or her parent were identified, other than by number.

The senior author and one or two assistants visited each classroom. The Pet Attachment Survey[3] (PAS) was utilized to ascertain the strength of the bond between the child and his or her pet. It consists of 27 statements to which the respondent indicates how he/she feels it applies to the relationship with their pet. Respondents are asked if the statement applies "almost always", "often", "sometimes" or "almost never". Examples of these statements are: "Within your family your pet likes you best" and "You like to touch and stroke your pet". Three of the 27 statements are negative towards pets e.g. "Your pet is a nuisance and a bother to you".

A profile of personality traits for each of the children was established by means of the Children's Personality Questionnaire[4] (CPQ) which is designed for children 8 to 12 years of age. It consists of 140 pairs of statements or questions. The respondent is asked, when given a pair of statements, to choose the one that best fits how they would react or feel in the described situation. When given a question, they are asked to choose the answer they feel is most correct.

The CPQ questions were read orally by a research assistant. This method resulted in all children answering the same question at the same time and eliminated them having to read the questions themselves. The PAS was explained and the first three statements only were read orally. The students were then encouraged to proceed at their own pace.

Data on past and present pet ownership of the child, as well as household demographics, were collected by having the parent complete one of two questionnaires. One questionnaire was designed for families with no pets and the other for those with pets. Demographic data were collected by means of twelve questions designed to determine, for example, type of dwelling and family structure. The socio-economic status (SES) of the household was calculated using the Socio-Economic Index of Occupations in Canada (Blishen and McRoberts, 1976). The children were also asked to complete questions regarding their age, grade and sex and the species of their favourite pet.

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ANALYSES

Data from the questionnaires were coded and entered into D-Base III (Ashton-Tate, 1984) files. The raw data were then visually checked for obvious errors and a number of consistency checks run.

Initially, the PAS results consisted of 27 values from 1 to 4 that corresponded to the value indicated by the child. For 23 of these, the higher the score, the more strongly the child agreed with the statement and hence, the more strongly bonded the child to the pet. For the remaining 4 questions, the statements were negative with regard to the pet so the score was reversed. Based on the results of a factor analysis performed by Holcomb et al., (1985), the developers of the PAS, the raw scores for 11 of the questions were averaged to form a continuous Intimacy (INT) variable which ranged from 1 to 4. Similarly, the scores from the remaining 16 were averaged to form a continuous Relationship Maintenance (RM) variable.

The responses to the 140 CPQ questions were formed into 14 scales or dimensions of the child's personality, according to the method described by Porter and Cattell (1975). Each new variable was comprised of the results of 10 of the raw CPQ scores and was assigned an alphabetic symbol for quick reference i.e. A, B, C, D, E, F, G, H, I, J, N, O, Q3 and Q4.

A variable "PETCARE" was created to describe the level of care given by the child to his/her pet. It was derived from the response given by the parent or guardian to the question "Does your child care for the pet or pets in your family?". The responses were assigned a value of 1, 2, 3 or 4, the higher values indicating more responsibility shown by the child toward the pet. Children who were not presently living in a household with a pet but who had had a pet within three years were considered, for purposes of further analyses, as "pet-owners".

Simple descriptive statistics were derived using PC-Statistical Analysis Systems (SAS Institute Inc., 1985). Then, unconditional and conditional associations between pet ownership status and demographic variables were examined. Specifically, pet owning children who had completed the PAS were divided into two groups; those who considered a dog or cat as their favourite pet and those who did not. For purposes of further analysis using PAS, only children in the first group were considered.

The two PAS variables, RM and INT, were considered as separate dependent variables. To decrease the possibility of chance inclusion in the final model, due to the large number of independent variables to be considered, independent variables were made available in three groups. The first group consisted of the 10 newly formed CPQ scores, the second of household

demographics and the third of personal data about the child e.g. age and grade. A separate stepwise least squares regression was performed on each of the three groups of independent variables. Any variable included in the model at a p-to-enter of <0.15 was retained for further analyses. All resultant variables from the three groups were then forced into a further model and retained if significant at $p<0.10$. Finally, PROC GLM in SAS was used for the remaining variables using an iterative process whereby the least significant one was eliminated such that in the final model only variables statistically significant at $p<0.05$ were retained.

RESULTS

A total of 312 children participated in the study. Of these, 243 (77.9%) had pets and 69 (22.1%) did not. One hundred and ninety-five (80.2%) of the pet-owning children returned completed parental questionnaires. Fifty-five (80.0%) of the non-pet owning children returned completed questionnaires. Of the children with no pets at the time of survey, 32 had had a pet within the last three years and so, for purposes of further analysis, were considered pet owners. The majority of children were 10 years old and in grade five.

The most common pet reported was 'dog' (61.5% of households) followed by 'cat' (54.9%). Over half of the children with pets had first experienced a pet when they were less than one year of age. Duties performed by the children with regard to caring for their pet ranged from feeding (87.2%) to exercising (46.1%) and grooming (33.8%). The species of pet referred to by the children when completing the PAS were 'dog' (45.3%) followed by 'cat' (33.7%).

The results of the two PAS scores, RM and INT, are presented in Table 1. The CPQ scores are shown in Table 2. Fourteen scores in total were recorded for all 312 children, with a possible range of 0 to 10. The means of 3 scores (E, N, and O) fell outside the expected range of 3.5 to 7.5 (Porter and Cattell, 1975).

The results of model formation for the dependent variables INT and RM are presented in Table 3. As can be seen, the variables PETCARE and CPQ factor 'C' were the only ones included in the final INT model at $p<0.05$. The regression coefficient for 'C' was positive, i.e. the value of 'C' increases as the value of INT increases. Factor 'C' is defined as: "high scorers appear relatively calm, stable, and socially mature for their age, and are better prepared to cope effectively with others than are low scorers, who are relatively lacking in frustration tolerance and more subject to a loss of emotional control" (Porter and Cattell, 1975). For PETCARE, the value '4', which refers to a child who cares for the pet all of the time, was referent variable for the

TABLE 1 Pet Attachment Survey Scores

	Category	N	Scale	Min	Max	Mean	Standard Deviation
1.	All pet-owning children	243	RM[1]	1.19	4.00	2.84	0.61
			INT[2]	1.55	4.00	3.11	0.59
2.	Children who responded regarding a dog or cat	192	RM	1.63	4.00	2.98	0.52
			INT	1.82	4.00	3.29	0.46
3.	Children who responded regarding a species other than a dog or cat	51	RM	1.19	3.81	2.33	0.66
			INT	1.55	3.91	2.47	0.56

[1] Relationship Maintenance
[2] Intimacy

TABLE 2 Children's Personality Questionnaire Results (n=312)

Scale	Min	Max	Mean	Standard Deviation
A	2	10	7.39	1.90
B	1	10	7.22	1.76
C	0	10	6.73	2.38
D	0	10	4.03	2.62
E	0	10	2.72	2.14
F	0	10	4.41	2.50
G	0	10	6.54	2.58
H	1	10	5.09	1.79
I	0	10	4.42	2.97
J	0	9	3.64	1.95
N	0	10	3.26	2.24
O	0	7	2.37	1.69
Q3	0	10	7.06	2.11
Q4	0	10	4.47	2.30

TABLE 3 Results of Least Squares Regression of "Intimacy" and "Relationship Maintenance" Bonding Factors on Child's Demographic and Household Demographic Variables, and CPQ Scores

Independent Variable	B[a]	SE B[b]	N[c]	p-Value[d]
Intimacy (R Square = 0.13)				
PETCARE				0.0142
1[e]	0.0140	0.3330	4	
2[f]	-0.3703	0.1168	42	
3[g]	-0.1619	0.1012	106	
4[h]	0.0000[i]	-.-	40	
'C'[j]	0.0546	0.0517	192	0.0007
Relationship Maintenance (R Square = 0.24)				
PETCARE				0.0059
1[e]	-0.6577	0.4887	4	
2[f]	-0.4122	0.1274	42	
3[g]	-0.1434	0.1102	106	
4[h]	0.0000[i]	-.-	40	
'C'[j]	0.0741	0.0181	192	0.0001
'Q3'[k]	0.0437	0.0197	192	0.0278
Blishen Score (SES)	-0.0064	0.0030	187	0.0319

[a] Estimated regression coefficient
[b] Standard error of the estimated regression coefficient
[c] Number of records in group
[d] Significance probability associated with the estimate B
[e] Child does not care for the pet
[f] Child cares for the pet occasionally
[g] Child cares for the pet some of the time
[h] Child cares for the pet all the time
[i] Referent dummy variable for the group
[j] Children's Personality Questionnaire score 'C'
[k] Children's Personality Questionnaire 'Q3'

group. A negative gradient was evident for the values '3' and '2' but not for '1'. The model for the PAS variable RM resulted in the inclusion of the following variables at $p<0.05$: CPQ scores 'C' (defined above) and 'Q3', socioeconomic status (SES), and PETCARE. The CPQ factor 'Q3' is defined in the following way: "this factor tends to reveal those who have strong control of their general behaviour, and who are especially socially aware and careful. Low Q3 indicates one who is not bothered by will control nor the regard for social demands. A child with a low Q3 score might, for example, be more frequently in trouble with school regulations, not with delinquent intent, but through carelessness and neglect." (Porter and Cattell, 1975). The regression coefficient was positive for 'C' and for 'Q3' and was negative for SES. For PETCARE, again the value of '4' was the referent value for the group, and a negative gradient was evident for the coefficient as the value of PETCARE decreased.

DISCUSSION

The aim of this study was to focus on the relationship between children and their pets, and to approach this in a rigorous manner using epidemiological techniques.

The sample of children was not collected in a random fashion, but rather as a convenience sample. While not ideal, due to the circumstances under which the study was conducted, this was the only way the sampling could be done. This may have resulted in some biases in the results. For example, the CPQ for this group of children had E, N and O scores that were more than one standard deviation of 2 less than the population mean of 5.5. This indicates that the study group of children were more obedient and mild (factor E), more naive and sentimental (factor N) and tended to feel more adequate and self confident (factor O) than what is considered average based on large population studies (Porter and Cattell, 1975). This finding was consistent across all schools studied. However, this should not greatly affect the overall results of the developed models as none of these factors proved to be significant in the Relationship Maintenance and Intimacy models.

The PAS scores indicated a fairly high level of attachment between the children and their pets, particularly to dogs and cats (Table 1). This finding may be somewhat misleading since the PAS is designed for use by dog and cat owners and contains questions that are not valid for owners of other pets. Questions such as "You like to have your pet sleep on your bed" cannot be ranked highly by owners of pets such as ponies or fish and thus will bring down the overall bonding score. A modified PAS or a modified means of deriving the scores for non-dog or cat pets would prove very useful in future. For this reason, children who responded to the PAS regarding a cat or a dog were considered separately from those who referred to another species.

The results of the administration of PAS compares quite well with Holcomb's validation data which indicated a minimum of 1.64 and 1.50 for INT and RM respectively, and a maximum of 4.00 and 3.81. Some differences may be due to the fact that Holcomb tested adults only. The bonding scores tend to be slightly higher for the children indicating a closer relationship between children and pets than between adults and their pets.

Highly significant differences exist between the children who are more strongly bonded to their pet and those who are not. The INT scale reflects attitudes regarding emotional importance of the pet as well as physical proximity or planning for physical proximity of the pet. RM refers to those behaviours broadly related to physical and sensual interaction with the pet, as well as, communication and investment of time and money into the pet.

On both the RM and INT scales, those children with higher scores also had higher ego strength. This factor was the only one that entered both models. Ego strength is a very significant dimension in an adult's personality, and knowledge regarding factors that can serve to strengthen this factor is useful to those involved in mental health care. According to Cattell (1965) a low C score indicates an individual who is easily swamped by his own emotionality, is subject to moods and a jaundiced attitude to life, and cannot adjust his behaviour to the realities of the situation. A low C score is the central feature of many kinds of psychopathology as it turns up in all varieties of neurotics (Cattell, 1965). Karson and O'Dell (1976), when discussing personality testing in adults, note that this factor is one of the most important indicators for a clinician seeking psychopathology as it measures ego strength or lack of neuroticism. These conclusions, however, relate to adults, not children. It is noted by Cattell (1973) that although it was at first felt that this factor was not measurable in children, he now believes it is. Although this study was an observational one and hence, does not indicate causal relationships, the association between bonding to a pet and ego strength warrants further investigation.

Children with higher RM scores would seem to be more controlled and socially precise as indicated by a higher Q3 score, while children with lower RM scores would be expected to be more casual. It is better for good mental health to be higher on Q3 (Karson and O'Dell, 1976). Q3 and C are both included in the second order CPQ "anxiety factor" and so one can expect scores of these to go up and down together (Karson and O'Dell, 1976). The significance of Q3 in the present study may relate to the sense of responsibility that a child develops in caring for his/her pet. Children bonded to their pets may follow a "timetable" when caring for his/her pet which may be related to a less casual personality. These children soon learn the consequences of neglecting to let the dog outside regularly or to

feed a cat. This study, however, did not attempt to explain the direction of effects.

Children with higher RM scores also came from homes of a lower socioeconomic status. Blishen and McRoberts (1976) developed the socioeconomic index based on the income level and education required for various occupations. They found that as one's income and education attained increases, so does one's SES score. The strength of the bond with a pet on the RM scale, therefore, is stronger in those children living in households where the parents or guardians are less educated and have a lower annual income. Table 3 results indicate that the more involved a child is in caring for their pet, the more strongly they are bonded with that pet on both the RM and INT scales. It could be that children bond with their pet more strongly if they are required to care for it on a regular basis but it could also be true that children will care for a pet more if they feel a strong bond with that pet. This relationship should be explored in future studies to discern what, if any, causal relationship exists.

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POTENTIAL APPLICATIONS FOR NON-INVASIVE MEASUREMENTS IN SMALL ANIMAL EPIDEMIOLOGY AND IN THE DETECTION OF STRESS

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Since the main content of this paper concerns the measurement of physiological variables associated with stress and/or hypertension, it may be asked if this has any strict relevance to epidemiology. The definition of epidemiology embraces the pattern of disease (i.e. frequency, distribution and cause), whether it is infectious or not. It is a recurrent feature of veterinary medicine compared with human medicine, that we have a paucity of reliable quantitative data concerning the pathophysiological, biochemical and epidemiological features, even of common diseases.

Regarding aetiology of disease, "stress" is all too frequently implicated, even today, in the loose fashion in which devils and goblins might have been involved in previous centuries. Yet it is measureable, provided a suitable constellation of techniques is applied and with adequate precision. This implies a combination of behavioural and physiological/ biochemical/immune-related criteria since no single factor is unambiguous. In particular, unique reliance on either cardiovascular or endocrine variables is potentially misleading especially when change in cortisol becomes the sole criterion (Michell, 1987).

The importance of non-invasive measurement is self-evident, not only on grounds of welfare, but also to avoid disturbing the system under observation. Thus restraint or even anticipation of sampling may provoke stress responses; in the field of human hypertension the "white coat" effect is a well-recognised problem.

The prevalence of hypertension in the veterinary field is really unknown despite a number of selective surveys in dogs and a minute amount of data in cats. Interpretation even of these sources is made difficult by variations in the fundamental principles underlying the measurement (e.g. whether invasive or not) and in detail of technique. Using oscillometric measurement of blood pressure as a non-invasive indicator of stress in dogs has led us to believe that it has great potential in establishing the true extent of hypertension in dogs. If so, this is important not only for veterinary medicine but particularly for human medicine since the dog has always been an important model in such research, also hypertension is one of the most expensive human diseases, with extremely unpleasant consequences.

It is worth noting that hypertension is no more than a statistical definition of the levels of systolic/diastolic pressure which, if exceeded, correlate with pathological effects. The reliability of any investigation of its epidemiology is therefore unusually dependent on precise studies of blood pressure and the factors affecting it in large and representative populations.

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The information described below forms part of a continuing project on stress in working dogs. The term stress is a very general notion and numerous definitions abound, for example:

"Stress: a physical, chemical or psychological factor or combination of factors that poses a threat to the homeostasis or well-being of an organism and that produces a defensive response as for example, physical or emotional trauma or infection" (Churchill, 1989). Physical criteria can be used as indices of stress responses. Three have been chosen in this study to complement behavioural data, namely:

(a) Hormonal changes
(b) Heart rate
(c) Blood pressure.

The population available for this study is provided by the Guide Dogs for the Blind Association.

METHODS

Hormonal changes

In man, salivary cortisol is considered the best physiological indicator of stress and is widely used in the field of psychobiology (Bassett *et al*, 1987; Kirschbaum & Hellhammer, 1989; Schreinicke *et al*, 1990). In farm animals, it is also generally regarded as the "stress" hormone in studies on welfare (Blackshaw & Blackshaw, 1989; Parrott & Misson, 1989; Fell *et al*, 1985; Fell & Shutt, 1986). In this project comparisons have been made between plasma and saliva cortisol in dogs (paper submitted for publication). Six dogs (not guide dog stock) were challenged with synthetic adrenocorticotrophic hormone (ACTH: Synacthen; Ciba Ltd., Horsham, W. Sussex) and near-simultaneous serial blood and saliva samples were collected at the following times: T0 (pre-challenge), T1 = 0.25h, T2 = 0.5h, T3 = 1h, T4 = 2h, T5 = 2.5h. Samples of saliva (0.5 ml or more) were obtained by wiping 2-3 veterinary cotton buds around the mouth of each lightly restrained dog. After centrifugation, the resultant fluid was freeze-stored until analysis by radioimmunoassay.

In order to confirm the practical relevance of this work, specifically to demonstrate a stress-response rather than one to ACTH, a pet dog was exposed to a natural stressor for that animal - namely noise from a domestic vacuum cleaner. Saliva samples were collected at time T0 (baseline); Ta = after 15 minutes of exposure; Tb = after 30 minutes of exposure; Tc = 15 minutes after cessation of noise; Td = 30 minutes after cessation of noise.

Heart rate

Sharp increase in heart rate marks emotional or physical anticipation (adrenalin-mediated or exercise-mediated). It is, however, also very labile, particularly in dogs as compared with man so there is a need for frequent successive measurements for adequate interpretation.

The equipment used in this study is a "Sport tester" (Model PE 3000: Polar Elektro KY, Finland), a telemetric fitness monitor for humans. Gel-electrodes attached to an elasticated band worn around the chest pick up and transmit heart signals to a watchstrap receiver.

Heart rate can be recorded every 5 seconds (minimum) so allowing good identification of environmental stimuli causing the change in rate. Apprentice guide dogs were chosen for their differing temperaments in order to assess heart rate changes during a training session lasting 20 minutes. In addition, readings were taken from a pet dog (as above) exposed to a known stressor (vacuum cleaner noise) for 15 minutes.

Blood pressure

This is monitored on an automatic oscillometric machine, the "Dinamap 1846" (Critikon). It has been widely validated in human medicine where it has few drawbacks and provides the "gold standard" among non-invasive techniques. Its application in canine cardiovascular medicine, including clinical hypertension, is currently being assessed (paper submitted for publication.)

A neonatal or paediatric cuff (depending on the size of dog) is wrapped around the base of the tail and after a 50-second inflation-deflation cycle readings of systolic, diastolic and mean arterial pressure and heart rate are obtained. Up to 10 measurements are recorded in a session and the subject remains standing throughout. Other workers have favoured limb readings from a recumbent posture, but standing is the most relaxed and reliable position for repetitive data collection, especially as guide dogs are used to frequent handling.

Data are presented for dogs with baseline readings taken in a neutral environment on two consecutive days (BL1 and BL2), in a veterinary clinic (VC), before (BW) and after work (AW) in harness. A few readings have been recorded from dogs in their kennels. Any "stress" associated with the clinic, or anticipation of work might be expected to raise blood pressure. In order to compare a known emotional response, readings were taken from the pet dog subjected to the noise stressor. The dog was in lateral recumbency (left) during the test period. Measurements were made pre-stressor (B), while the vacuum cleaner was switched on (C) and post-stressor (D and E).

RESULTS

Salivary cortisol

The assay results represent "free" cortisol and correlation between saliva and plasma is good ($r = 0.877$; $P < 0.001$), saliva concentrations being 4-10% of those in plasma. Table 1 shows mean changes in cortisol concentration following ACTH challenge in the six dogs. Maximum mean plasma values were seen at sample time T3 and for saliva at T4. Statistical analysis by Kendall's rank correlation produced a coefficient $r = 0.706$ (NS) for plasmas and $r = 0.833$ ($P < 0.001$) for salivas. The percentage increase from baseline values was higher for saliva than plasma (except for $T = 1$).

Values obtained from a pet dog (Table 2) indicate that peak salivary cortisol concentrations may not have been reached even 15 minutes after start of exposure to the subject-specific stressor; the maximum value seen was at time Tb (30 minutes' exposure). In addition, hormone concentrations were still well above baseline even 0.5 hour post-stressor.

Table 1. Mean changes in cortisol concentration (nmol/l) following injection of ACTH

	T0	T1	T2	T3	T4	T5
Plasma						
x	86.2	278.7	366.5	537.7	434.8	209.7
se	10.0	25.3	36.6	52.8	74.8	35.0
Saliva						
x	5.3	11.6	23.2	39.3	41.9	20.9
se	0.9	1.9	2.8	6.8	9.8	4.4

Table 2. Saliva cortisol concentrations (nmol/l) in a pet dog exposed to a noise stressor

T0	Ta	Tb	Tc	Td
1.0	1.8	11.4	10.7	7.2

Heart rate

Only a small amount of information has been collected so far using the Sport tester. Data from dogs of differing temperament show that heart rate fluctuations were much greater in excitable individuals compared with relaxed dogs, with large increases in response even to familiar situations. Around the same training circuit, the range for an example of an excitable dog was 68-236 beats per minute (BPM) and for a calmer type was 55-172. The pet dog exposed to the sound stressor showed heart rate changes from a resting value of around 30/min to varying rates in the range 90-173.

Blood pressure

Table 3 shows a sample population of 20 dogs (reduced to 16 in two instances) which illustrate some general observations. Statistical analyses were carried out by paired t-tests. Results were remarkably similar for each individual; even day-to-day variations were small. Spearman's coefficient of rank correlation was calculated for indices in BL1 versus BL2: it was significant at $P < 0.002$ for systolic ($r = 0.659$) and $P < 0.01$ for diastolic values ($r = 0.574$). Significant increases were noted in blood pressure in the veterinary clinic. Anticipation of work significantly raised systolic pressure which returned to baseline subsequently; heart rate also fell significantly after work.

Table 3. Mean (± se) blood pressures (mmHg) and heart rates (BPM)

	N	SYS	DIAS	MAP	BPM
BL1	20	105 ± 1.7	57 ± 1.5	77 ± 1.8	98 ± 3.0
BL2	20	105 ± 1.9	56 ± 1.4	77 ± 1.5	93 ± 2.1
VC	20	111 ± 2.7	60 ± 2.0	82 ± 2.0	102 ± 3.2
BW	16	110 ± 2.1	58 ± 2.0	80 ± 2.3	98 ± 2.8
AW	16	105 ± 1.8	56 ± 1.6	77 ± 2.0	89 ± 3.1

Significant differences:

P<0.01 SYS: BL1 & VC; BPM: BW & AW
P<0.02 SYS: BW & AW
P<0.05 SYS: BL1 & BW; DIAS: BL1 & VC; BPM: BW & AW

Lateral recumbency increased diastolic blood pressure and decreased heart rate in the pet dog in comparison with test readings taken standing up (A, Table 4). The vacuum cleaner noise raised all criteria dramatically, heart rate by a factor of 2.5. For comparative purposes post-stressor data are grouped as the first 10 readings (D) and then 10 readings after approximately 15 minutes (E). Twenty-five minutes after the cleaner had been switched off, readings were still above baseline, although behavioural observations suggested superficial calmness.

Table 4. Effect of a noise stressor on blood pressure (mmHg) and heart rate

	SYS	DIAS	MAP	BPM
A	104 ± 3.5	54 ± 2.0	77 ± 1.8	60 ± 4.1
B	101 ± 1.5	69 ± 3.3	84 ± 2.0	46 ± 1.7
C	134 ± 3.4	79 ± 2.6	106 ± 2.2	117 ± 9.4
D	120 ± 2.1	67 ± 3.5	91 ± 2.4	55 ± 3.0
E	111 ± 1.5	61 ± 2.6	82 ± 2.6	55 ± 1.1

Significant differences:

P < 0.001 SYS BC, BD, BE; DIAS AB; MAP BC, CD; BPM BC, CD, BE
P < 0.01 SYS CD, DE; BPM AB
P < 0.02 DIAS CD; MAP AB, DE; BPM BD
P < 0.05 DIAS BC; MAP BD

DISCUSSION

Salivary cortisol

There was some variability in readings but correlation between plasma and salivary cortisol was good. Saliva values were 10% or less of those in blood. The saliva readings represent "free" cortisol and, as in other work (Parrott *et al*, 1989) showed a greater relative increase from baseline after ACTH stimulation. This was presumably because the "free fraction" in blood increased relative to the bound cortisol.

There was evidence of delay in increase of salivary cortisol compared to blood. This lag could not be quantified accurately as sampling was not continuous. There was a delay, too, in the expected increase in salivary cortisol of the pet dog in response to the sound of the vacuum cleaner despite the behavioural changes which were noticed immediately. The interesting result was the small decrease in cortisol even 15 minutes after the machine had been switched off. After a further 15 minutes, when behaviour was considered to be relaxed on casual observation, cortisol was still considerably higher than baseline.

Heart rate

There have been studies of heart rate in relation to behaviour in man (Strand, 1978; Smith & Kampine, 1980) and in other animals e.g. sheep (Baldock *et al*, 1987; Baldock *et al*, 1988) which indicate that correlations with environmental variables and individual identity could have important implications for long-term health. The results obtained so far from this study show that large sudden and maintained heart rate increases from resting levels are good indicators of emotional state, as one might expect from adrenalin-mediated "fight or flight" responses. The particularly interesting finding from these results is the great heart rate fluctuation observed in a highly excitable dog even when training on a familiar route.

Blood pressure

Preliminary studies showed that limb readings produced highly variable results, partly due to difficulty in keeping dogs sufficiently still, but perhaps also due to conformation. Tail readings were more promising with greater tolerance of the inflatable cuff. Sessions lasting 10 minutes or so indicated that it was generally easier to restrain dogs standing rather than lying, the exception being the pet dog when subjected to noise stress.

Repeatability of the method was demonstrated by the similarity of BL1 and BL2 values in the 20 dogs. Heart rate on day 2 was a little lower, perhaps indicating that the procedure was more familiar. The raised readings in clinic were probably due to stress of anticipated physical interference based on previous experience. Comparisons of pre- and post-work showed higher values in the first case, and readings similar to baseline for the second, except for lower heart rate. Pre-work readings were presumed to be due to excitement rather than anxiety. If the work caused anxiety in general, then greater increases in readings might have been seen at the end of the work period. These are speculations and serve as a reminder of the importance of using a battery of tests to evaluate emotional responses, notably stress.

The behavioural observations of the pet dog were unequivocal: shivering started as the cleaner was switched on; this was followed by hyperventilation, dilated pupils, tenseness of somatic muscles, even those of the face, and a need to orientate to the source of sound. To the authors' knowledge, the dog had no specific reason to fear such an appliance! Baseline readings taken in a standing position were similar to the group mean of the 20 dogs, except for heart rate - always low in this dog. Recumbency significantly increased diastolic and mean arterial pressures and decreased heart rate. The noise stressor greatly increased all indices, heart rate by a factor of 2.5.

The relatively low pressures and heart rates seen here compared with results of other workers (Coulter & Keith, 1989; Hamlin *et al*, 1982; Pettersen *et al*, 1988) probably reflect two factors:

a) The use of a "relaxed" type of dog (mainly labradors) accustomed to a variety of experiences with many handlers.

b) The preference for a natural standing position with minimal restraint and the tail lightly steadied in line with the back.

A separate study of Dinamap pressures versus direct pressure measured in different arteries in both anaesthetised and conscious dogs is being carried out to confirm this view (Tempest *et al*, 1992). True resting blood pressures and heart rates, i.e. in calm and relaxed dogs, may indeed be lower than previously believed. One of the factors causing age-related changes in blood pressure is excessive salt intake (Michell, 1989) so another study is in progress on age-related changes in canine blood pressure.

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OPEN SESSION

A DESCRIPTIVE STUDY OF DISEASES IN LAMBS IN EARLY LAMBING FLOCKS

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Accurate and objective data collection is the basis of both descriptive and analytical epidemiology. Because of the difficulties in obtaining such information there is little representative data on disease at farm level. Recently we carried out a two year study of diseases in lambs in intensively reared (housed) flocks. In this paper we discuss methodological problems associated with obtaining this information. Results from the study will be included in the oral presentation.

Early lambing (housed) flocks are gaining popularity in the UK. Ewes hormonally induced into early oestrus lamb in December or early January. Lambs and ewes are loose-housed on straw. Weaning takes place when lambs are six weeks old. Lambs have access to commercial concentrate food, straw, silage and water pre-weaning; post-weaning to straw, concentrate, and water. Lambs are slaughtered from ten weeks of age, peaking at 15 weeks. This system is contrary to the traditional extensive systems of rearing lambs. This project was designed to determine the prevalence of disease in housed lambs and their influence on production.

Two different methods of data collection were used. In year one a cohort of lambs on three farms was followed prospectively, lambs were clinically examined for signs of disease each week. In year two of the study sick lambs were presented by the farms for treatment, diseases were recorded from these sick lambs. Dead lambs were post mortemed and slaughtered lambs monitored for sub-clinical disease in years one and two.

First Year Experimental Design And Problems

Ideally a random sample of farms using the early lambing system should have been selected for study but manpower and financial constraints made this impractical. Twelve farms which slaughtered lambs through an abattoir in Devon were approached. Three followed the above system, were situated within 50 miles of the veterinary school and were willing to co-operate. All three farms entered the study.

A pilot study to investigate the time taken to examine a lamb had been carried out. 80 lambs could be examined in eight hours of daylight. The previous years lambing percentage was

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used to estimate the number of ewes required to produce 80 lambs on each farm. Ewes were then randomly selected pre-partum.

Each farm was visited on a Monday, Wednesday or Friday and a cohort of 80 lambs examined. There were 594, 757 and 769 lambs born on each farm. A disease detection level of 3.6% with 95% confidence can be obtained from 80 lambs. Diseases lasting less than one week were less likely to be detected than those of more than seven days duration leading to length bias, but weekly examination of lambs was the shortest interval feasible. Diseases recorded were chronic rather than acute eg. conjunctivitis, entropion, respiratory disease and anaemia.

A protocol was developed to ensure that all lambs were examined thoroughly and impartially. Clinical examination of lambs involved two researchers. Lambs were examined for signs of health and disease, weighed on a suspended scale (Salter, West Bromwich, UK), temperature was recorded using a digital thermometer and faeces samples examined for *Campylobacter* spp, *Salmonella* spp and coccidia.

A pressure sensitive data capture pad, Multipad,(Perex, Reading, UK) was programmed to prompt examiners to follow the examination protocol and record results from clinical examinations. Data recorded was down-loaded onto micro-computer and stored in dBase III+ (Ashton-Tate) at the end of every day. Although this pad performed well in trials it was not durable on farms and because of its unreliability its use was abandoned.

A total of 2120 lambs were ear-tagged at birth. Farms were provided with different designs of tag to investigate tag performance. Of the three ear-tag designs used, RD2000 (Ritchey Taggs, Ripon UK) were lost in 1% of lambs whilst Aussie type I tags (Ritchey UK) and Rototag (Dalton Supplies, Henley UK) were lost in 2.5% of lambs.

Farmers were provided with a book to record date of birth, ewe and lamb identification and fostering. All farms filled this in during lambing but on each farm replication errors occurred.

Farmers were provided with a 11 cu ft capacity refrigerator in which to store all dead lambs for collection on alternate days. A pilot study comparing freezing with refrigeration on carcase preservation and decomposition had resulted in refrigeration being the preferred option. Frozen carcases took up to two days to thaw out and abdominal contents were destroyed by freezing. Refrigeration preserved carcases for up to five days. A protocol to ensure dead lambs were thoroughly and objectively necropsied was developed prior

to year one. 236 lambs were post mortemed during the first year.

Abattoir monitoring was developed to ensure that carcase, lung, heart and liver were examined for signs of disease and correctly matched with the dead-weight, carcase conformation and fat classification of slaughtered lambs. Two researchers were required. 1820 lambs were slaughtered in year one.

At the end of the first year farmers had become quite involved in the study and were interested in participating in the second year. Results from the first year indicated prevalence of disease was lower than anticipated and that diseases of short duration were not detected. The design of the study was changed as described below in an attempt to record such diseases.

Second Year Experimental Design And Problems

Objective examination of a cohort of lambs was replaced with presentation of sick lambs by farmers. To encourage presentation lambs were treated by the researcher but medication was paid for by the farmer. Only one researcher was required and each farm could be visited daily. Each visit took approximately one hour after birth weights had been recorded. Despite previous agreement from all three farms to this change in design one farm did not co-operate because they did not treat sick lambs.

More acute diseases were recorded eg meningitis, and diseases of lower prevalence eg contracted tendons. Diseases requiring close examination eg anaemia or conjunctivitis were presented less frequently than in the previous year's study.

Ewes were condition scored at regular intervals and all lambs on the farm were weighed at birth, weaning and pre-slaughter to provide information on which to base importance of diseases in terms of maternal input and lamb growth.

RD2000 tags were used on all farms for the second year of study, 0.9% of lambs lost tags. The recording book contained the ear tag numbers of ewes pre-printed and typed self-adhesive labels for lamb identification were provided to avoid repetitions. Two farms used this record book but said that labels were small and difficult to handle, the third refused because lambs were being weighed during lambing and he maintained that the researcher could record this information. Unfortunately this meant many lambs born dead and fostered lambs were not correctly recorded.

Data from dead and slaughtered lambs was recorded in year two using the same methods as those used in year one. 197 lambs died, 2118 were slaughtered.

Conclusions: Pilot studies reduced methodological errors during the study period. Data on dead and slaughtered lambs was informative and of a high standard. In the first year recording disease using a cohort of lambs was objective but diseases of low prevalence or short duration were missed. In the second year diagnosis of disease via treatment was more subjective but a wider range of diseases was detected.

DISTRIBUTION OF SUBCLINICAL MASTITIS IN QUARTERS IN RELATION TO THE CAUSAL MICROORGANISMS

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Mastitis is one of the oldest and most investigated diseases in veterinary medicine. However, very little information is available on some basic epidemiological aspects such as its prevalence and incidence, distribution within quarters, and risk factors. Moreover, in recent years coagulase-negative *Staphylococci* and a large number of environmental *Streptococci* have been recognised as mastitis pathogens, adding new problems and stimulating studies on risk factors, and the spread and prevention of these infections. Meanwhile, there is increasing knowledge about immunological influences on the development of mastitis. Thus, the pathogenesis, prevention and therapy of mastitis, in which pathogens such as *S. agalactiae*, *Staph. aureus*, *S. uberis*, *S. dysgalactiae* are incriminated, should be re-evaluated.

With this background, we designed a research project to study the distribution of infections and risk factors for clinical and subclinical mastitis in our environment.

In this paper the preliminary results on distribution of infections are presented, with special attention being paid to the spread of infection within quarters in relation to the different microorganisms.

MATERIALS AND METHODS

Quarter milk samples were collected from 10 different herds from Northern Italy. The characteristics of the herds are shown in Table 1.

Table 1. Herd characteristics

HERD	PROVINCE	COWS SAMPLED	HOUSING	SAMPLING PERIOD	SAMPLES
A	Verona	70	loose-yard	8 months	281 (4.5%)
B	Varese	40	cowsheds	24 months	373 (6.0%)
C	Milano	150	loose-yard	12 months	424 (6.8%)
D	Brescia	130	cubicles	12 months	468 (7.6%)
E	Verona	160	loose-yard	8 months	496 (8.0%)
F	Cremona	150	cubicles	12 months	562 (9.1%)
G	Cremona	190	loose-yard	12 months	722 (11.7%)
H	Cremona	300	loose-yard	8 months	845 (13.6%)
I	Milano	270	loose-yard	12 months	905 (14.6%)
L	Milano	280	loose-yard	12 months	1116 (18.0%)

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All the cows were milked in milking parlours, with the exception of cows in herd B which were milked with via fixed milking pipeline. The level of hygiene in all herds was acceptable or good, and chlorhexidine teat dipping was applied in all herds. Quarters were sampled according to I.D.F. recomendations (FIL-IDF, 1987) at calving and drying off, and at least every 3 months. In herd B, all clinical cases were collected, too. Samples were plated on 5% blood agar plates and, when suspect colonies had a concentration equal to or over 100 UFC/ml, they were identified following standard microbiological procedures (biochemical tests and the API system - Bio Merieux, Italy). Coagulase-negative *Staphylococci* and environmental *Streptococci* strains were grouped together because of the difficulties in identifying all of the strains.

Data were stored in DBIV (Ashon Tate, USA) and analysed using the SAS package (SAS Institute, USA).

RESULTS

Distribution of infections

We sampled 1,740 cows for a total of 24,768 quarter samples. In the analysis, the individual sample - not the cow - was the experimental unit.

Overall, 42.8% of cows were infected at least in one quarter. The prevalence of infection in the different quarters is reported in Table 2. A total of 17.97% of quarters were positive. The distribution of positive samples was different between quarters, with a minimum in the left front quarter (15.67% of quarters) and a maximum in the left rear quarter (19.83% of quarters).

Table 2. Distribution of infections

	Quarters									
	Left front		Right front		Right rear		Left rear		Totals	
Neg.	5165	83.41%	5978	82.01%	4939	79.76%	4928	79.59%	20110	81.19%.
Pos.	970	15.67%	1057	17.07%	1195	19.30%	1128	19.83%	4450	17.97%
Miss.	18	0.29%	31	0.50%	35	0.57%	26	0.42%	110	0.44%
Blind	39	0.63%	26	0.42%	23	0.37%	10	0.16%	98	0.40%
Totals	6192		6192		6192		6192		24768	100%

The prevalence of the microorganisms in the positive samples is given in Table 3. Coagulase-negative *Staphylococci* (CNS) represent the major source of infection, with a range between 39.45% (RF) and 42.91% (LR) of the positive samples, confirming the growing concern about these pathogens (Watts & Owens, 1989).

Contagious pathogens (*S. agalactiae* and *Staph. aureus*) are also well represented, with overall frequencies of 7.6% and 13.91%, respectively (Table 3).

Table 3. Prevalence of microorganisms

	LF		RF		RR		LR		Totals
Co-neg.*Staphs*	408	42.06%	417	39.45%	489	40.92%	527	42.91%	1841 (41.37%)
Staph.aureus	157	16.91%	171	16.17%	148	12.38%	143	11.64%	619 (13.91%)
Str.agalactiae	73	7.52%	90	8.51%	77	6.44%	98	7.98%	338 (7.60%)
Str.dysgal.	62	6.39%	63	5.96%	90	7.53%	99	8.06%	314 (7.06%)
Str.uberis(1-2)	35	3.61%	36	3.40%	60	5.02%	65	5.29%	196 4.40%)
*Str.*spp.	51	5.26%	83	7.86%	120	10.04%	106	8.63%	360 (8.09%)
Aeroc.viridans	59	6.08%	72	6.81%	72	6.02%	74	6.02%	277 (6.22%)
E.coli	33	3.40%	30	2.84%	49	4.10%	41	3.33%	153 (3.44%)
Coliforms	33	3.40%	34	3.21%	42	3.51%	30	2.44%	139 3.12%)
*Coryneb.*spp.	38	3.91%	42	3.97%	31	2.59%	31	2.52%	142 (3.19%)
Others	21	2.16%	19	1.80%	17	1.42%	14	1.14%	71 (1.60%)
Totals	970	21.79%	1057	23.75%	1195	26.85%	1228	27.59%	4450

Of note is the prevalence of *Aerococcus viridans*, a streptococcus species recently recovered from milk samples (Watts, 1990; Zecconi *et al.*, 1990), which achieves a value close to the prevalence of *S. dysgalactiae*, and 1.5 times that of *S. uberis*.

Most of the samples derived from routine sampling, and this could explain the low prevalence of *E. coli* and coliforms. However, our laboratory data show a lower prevalence in comparison with the data generally reported in the literature, even for clinical mastitis (unpublished data).

The distribution of infected quarters in each udder is presented in Table. 4. The expected distribution of quarters infected was computed under the hypothesis of the binomial distribution with p = 0.1797 (from Table. 2); in other words, our hypothesis was independent of quarters within the udder. The goodness- of- fit analysis (Chi square test, 3 d.f.) showed a significant difference between expected and observed values ($p<0.0000$) and the hypothesis should be rejected.

The distribution of infected quarters for each group of microorganisms are shown in Table 5. The pathogens were categorised into 5 groups: CNS, contagious (*S.agalactiae* and *Staph.aureus*), environmental *Streptococci*, coliforms and others.

Table 4. Distribution of infected quarters

Quarters infected	Observed	Expected p=0.1797
None	3526	2803.6
1	1502	2456.7
2	662	807.3
3	320	117.9
4	166	6.5

Table 5. Distribution of infected quarters/microorganism

	Infected quarters 1	2	3	4	Totals	p
Co.Neg.*Staphs*	622	172	82	44	920	0.3772
Contagious	260	99	51	27	437	0.4113
Envir.*Strep*	463	70	21	10	564	0.3129
Coliforms	100	11	13	6	130	0.3558
Others	57	17	5	2	81	0.3519
Totals	1502	369	172	89		

We assumed that the theoretical distribution was binomial, conditioned by the presence of at least one quarter infected:

$$P_n = (b*p^n*q^{4-n})/[1-(1-p)^4],$$

where p_n = probability of n quarters infected
b = binomial coefficient
p = frequency of quarters infected within each group of microorganisms (Table. 5).

In all the cases, the goodness-of-fit analysis with the Chi-square test (2 d.f.) was significant, and the hypothesis was rejected. We calculated the Chi-square value (12 d.f.) on the whole table to test the homogeneity. In this case, the value (78.12) also was significant, and the hypothesis was rejected.

From Table. 2 and from the previous analyses it was clear that there was a different distribution of infections within the udder using the coding reported in Table. 6. In this case, our hypothesis was that the distribution of infection within quarters should be uniform, when the same number of infected quarters was considered. Considering data in Table. 7, the hypothesis should be rejected in the classes: 1 infected quarter (Chi square = 25.66, 3df, $p<0.005$); 2 infected quarters (Chi square = 66.94, 5 df, $p<0.005$); and 3 quarters infected (Chi-square = 10.48, 3df, $p<0.05$).

The same analyses were applied to the different groups of microorganisms, considering only quarters with infections due to the same microorganism (Tables 8, 9 and 10), and which had at least 5 positive samples in each cell. The distributions of CNS, contagious pathogens

and environmental *Streptococci* differed significantly both when 1 quarter or 2 quarters were infected, confirming the higher frequency of infections in rear quarters.

Table 6. Coding of quarter infections

Infected quarters	A	B	C	D	E	F
1	Left front	Right front	Right rear	Left rear		
2	L.R.+R.F	L.F+R.R	L.F.+L.R.	R.F.+L.R.	R.F.+R.R.	R.R.+L.R.
3	no L.F.	no R.F.	no R.R.	no L.R.		

Table 7. Distribution of infections within the udder

Infected quarters	A (exp)	B (exp)	C (exp)	D (exp)	E (exp)	F (exp)
1	311 (375.5)	347 (375.5)	409 (375.5)	435 (375.5)		
2	96 (110.6)	85 (110.6)	94 (110.6)	98 (110.6)	101 (110.6)	188 (110.6)
3	105 (80)	72 (80)	70 (80)	73 (80)		

Table 8. Distribution of infections within quarters (1 infected quarter)

	L.F.	R.F.	R.R.	L.R.	Chi sq.	d.f.	p<
Co.-neg.*Staphs*	136	125	168	193	18.48	3	0.005
Contagious	61	82	50	67	8.22	3	0.05
Environ. *Strep.*	78	99	141	145	27.63	3	0.005
Coliforms	19	23	35	23	5.65	3	0.10
Others	17	18	15	7	5.25	3	0.10
Totals	311	347	409	435			

Table 9. Distribution of infection within quarters (2 infected quarters)

		A	B	C	D	E	F	Chi	p
Co.-neg.*Staphs*		18	20	24	24	26	60	42.60	0.005
Contagious		12	5	6	9	7	12	4.52	0.025
Environ.*Strep.*		11	5	4	9	5	14	6.30	0.500
Totals	41	30	34	42	38	86			

Table 10. Distribution of infection within quarters (3-4 infected quarters)

	3 infected quarters				4QT
	A	B	C	D	
Co.Neg.*Staphs*	23	13	26	20	44
Contagious	12	15	11	1127	
Totals	35	28	37	31	71

DISCUSSION & CONCLUSION

The distribution of infections within quarters is one of the major problems in evaluating epidemiological and therapeutical data. There are some reports that quarter infections are not independent (Hueston, 1988; Thornburn, 1990), but other reports of independence of clinical infections (Gonzales *et al.*, 1990). Our data confirm that quarter infections are not independent.

The microbiological assays on quarter milk samples showed that at least 17.97% of quarters and 42.8% of cows were infected, and confirms that CNS are the major source of infections in our herds. However, their role in developing clinical mastitis, increasing somatic cell counts and decreasing production is not fully understood and should be investigated further. Moreover, other microorganisms, such as *Aerococcus viridans*, have a high prevalence. More investigations of the pathogenesis of those microorganisms which appear to be increasing in importance are justified.

The need for more studies on infection models is confirmed by the significantly higher prevalence of overall infections in rear quarters. Moreover, CNS and environmental *Streptococci* were more frequently recovered in the rear quarters in any combination, while the same pattern was not found for the other pathogens. The CNS and environmental *Streptococci* groups include many different strains, and this could bias the results. However, evidence of the higher prevalence in rear quarters is clear and is consistent with the results on clinical mastitis of Angier & Austin (1987), Sastry *et al.* (1988) and Gonzales *et al.* (1990).

The results pose new questions on the pathogenesis of these infections. One possible explanation of these results could be that rear quarters are exposed more frequently to environmental pathogens on bedding, and to stress related to the greater yield of rear quarters.

All of these issues should be resolved by increasing our knowledge of the pathogenesis of the relevant microorganisms, the relationship with immunological defences, and the most common risk factors (machine milking, bedding, housing etc.), and by developing epidemiological models that could help in acquiring knowledge and determining strategies for the control of the disease.

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ADVENTITIOUS BURSITIS OF THE PIG HOCK

SOME EPIDEMIOLOGICAL ASPECTS

W. J. SMITH*

An adventitious bursa is an acquired well defined sac of fluid which arises in the subcutaneous connective tissue as a response to chronic low grade trauma. (Le Gros Clarke, 1958) Adventitious bursae have been described in man (Turek, 1977), cattle (Weaver, 1986), horse (Adams, 1974) and dog (Johnston, 1979).

Bursitis was first reported in the pig in Sweden (Sandstedt & Carlquist, 1951). Soon after, bursitis was reported from most countries rearing pigs intensively and the reported prevalence has varied from 36% (Backstrom & Henricson, 1966) to 73.4% (Penny & Hill, 1974). The pig industry in the UK has intensified markedly since the latter workers reported their findings. A study of pigs at Scottish abattoirs and on farms was undertaken to establish the prevalence and severity of bursitis as well as its relationship to other factors especially the physical environment (Smith & Smith, 1988).

ABATTOIR SURVEY

Visits were made to five abattoirs in Scotland: two in the South-East of Scotland, one in mid-Scotland and two in the North-East of Scotland. Two of these abattoirs killed pigs exclusively. Data were collected from 14,046 pigs from 146 farms which broadly represented 46 small farms, 47 medium sized farms and 53 large farms producing less than 25 pigs, 25-50 pigs or more than 50 pigs per week respectively. The farms were evenly distributed throughout Scotland in relation to the pig density of the various areas. Data collected during the month of October to April were designated winter data while those collected over the period May to September were referred to as summer data. The following data were collected: slapmark (farm of origin), sex, presence or absence of adventitious bursae of the hock on either leg, location of bursae, bursal score (estimation of size) and the presence or absence of capped hock. In addition, samples were occasionally collected for cytological, histopathological and anatomical studies, while other measurements such as skin thickness, leg length and hair thickness were made for special studies.

The hocks were scored on a subjective basis from 0-4, where 0 = normal (i.e. no bursa) and 4 = maximum size.

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RESULTS

Prevalence and severity

During the survey 14,046 pigs were examined and of those 87.0% had evidence of bursitis. The mean score was 1.598. Bursitis was noted in the left leg of 11,579 pigs (82.436%) and in the right leg of 11,588 (82.286%) of pigs. The prevalence is considerably higher than the figure of 73.4% reported by Penny and Hill (1974) in the U.K. More recently, in Germany, Probst et al., (1990) reported a prevalence of nearly 90% in finished pigs but only 223 pigs were examined.

The effect of sex and season

The number of pigs examined and the mean bursitis score for males and females is noted in Table 1.

Table 1

	Sex	No. of pigs	Mean bursitis score
Winter	M	5061	1.663
	F	4656	1.641
	Total M+F	9717	1.652
Summer	M	2289	1.509
	F	2040	1.438
	Total M+F	4329	1.476

The pigs came from 138 farms in winter and 89 farms in summer. The mean score for males in winter was higher than for females in winter and summer and for males in summer. The mean score for females in winter was higher than for females in summer.

The difference might be partly explained by the fact that the average weight of males at slaughter was 90.2 kg while that for females was 85.4 kg. The severity of bursitis tends to increase as weight increases (Probst et al., 1990 & Berner et al., 1990). Stocking density tends to increase in the winter in Scotland and this may also explain the seasonal difference to some extent. No effect of sex on prevalence was noted by Backstrom and Henricson (1966) and Orsi (1967) but Penny and Hill (1974) reported a higher prevalence in males (72.6% v. 70.8%).

Relationship to farm output

As the pig industry has intensified pig units have become bigger with more animals per m^2, more animals per stockperson and less bedding per animal. The severity of bursitis was noted in pigs produced by small farms, medium sized farms and large farms, there being 46, 47 and 53 farms in each category respectively. The number of farms producing pigs with bursitis scores ranging from 0-0.4 to 2.2-2.8 in each farm group is shown in Table 2.

Of the small, medium and large sized farms, 11 (23.91%) farms, 20 (42.50%) farms and 37 (69.18%) farms respectively produced pigs with a mean score greater than 1.6. Thus, as farm output (size) increases, a higher proportion of farms are likely to produce pigs with a significant degree of bursitis, indicating that conditions conducive to the development of bursitis are more likely to be present on large farms.

Table 2: The number of farms producing pigs in each scoring group

	Farm size		
Bursitis Score	Small (46) No. of farms	Medium (47) No. of farms	Large (53) No. of farms
0-4	8	3	1
0.5-0.8	6	8	1
0.9-1.2	10	7	2
1.3-1.6	11	9	12
1.7-2.0	9	15	17
2.1-2.4	1	4	16
2.5-2.8	1	1	4

Bursal distribution and seasonal effect

Bursae on the plantar and lateroplantar aspects have been noted by Penny and Hill (1974), Backstrom and Henricson (1966), Behrens and Trautwein (1964), Berner **et al.**, (1990) and Probst **et al.**, (1990). However, Groch **et al.**, (1986) noted bursae on the medial plantar aspect of the hock as well as on the other two common sites. The distribution of bursae was noted at the abattoir and the results are noted in Tables 3a, 3b and 3c.

Table 3a: The number (%) of pigs with **plantar** bursitis

	Number (%) of pigs affected		
Site	Winter (%)	Summer (%)	Total (%)
Left leg	638 (4.54)	442 (3.15)	1080 (7.69)
Right leg	679 (4.83)	395 (2.8)	1074 (7.65)
Both legs	6410 (45.64)	2273 (16.18)	8683 (61.82)
Neither leg	1990 (14.17)	1219 (8.68)	3209 (22.85)
Total	9717 (69.18)	4329 (30.82)	14046 (100.00)

Table 3b: The number (%) of pigs with **lateroplantar** bursitis

Site	Number (%) of pigs affected		
	Winter (%)	Summer (%)	Total (%)
Left leg	466 (3.32)	271 (1.93)	737 (5.25)
Right leg	427 (3.04)	327 (2.33)	754 (5.37)
Both legs	678 (4.83)	394 (2.81)	1072 (7.63)
Neither leg	8146 (58.00)	3337 (23.76)	11483 (81.75)
Total	9717 (69.18)	4329 (30.82)	14046 (100.00)

Table 3c: The Number (%) of pigs with **medial** bursitis

Site	Number (%) of pigs affected		
	Winter (%)	Summer (%)	Total (%)
Left leg	222 (1.58)	169 (1.20)	391 (2.78)
Right leg	293 (2.09)	254 (1.81)	547 (3.89)
Both legs	441 (3.14)	229 (1.63)	670 (4.77)
Neither leg	8761 (62.37)	3677 (26.18)	12438 (88.55)
Total	9717 (69.18)	4329 (30.82)	14046 (100.00)

These data show that all three lesions are much more likely to be bilateral than unilateral. The prevalence of all lesions is higher in the winter than summer, especially when both legs are affected. In Scotland, stocking density tends to be higher in winter and this may partly explain the difference in prevalence. When a bursa was present in one leg only there was no difference in the prevalence between right and left. These findings would indicate that most pigs behave in a fashion which does not discriminate against either leg. However, the data also indicates that pigs sit or lie in a fashion which tends to induce plantar bursitis rather than medial or lateroplantar bursitis.

The various permutations of bursae which may occur are noted in Table 3d.

Table 3d: The various permutations of bursae which occurred in both hind legs

Site	No. of pigs	%	No. of pigs	%
	Left leg		Left leg	
P only	8842	(62.95)	8675	(61.76)
LP only	1575	(11.21)	1524	(10.85)
M only	121	(0.86)	135	(0.96)
P + LP + M	13	(0.09)	18	(0.13)
P + LP	101	(0.72)	142	(1.01)
P + M	807	(5.75)	922	(6.56)
M + LP	120	(0.85)	142	(1.01)
No bursitis	2467	(17.56)	2488	(17.71)
Total	14046	(100.00)	14046	(100.0)

P = plantar LP = lateroplantar M = medial

Once again these data show that the prevalence for all combinations is remarkably similar in both legs. However, it is difficult to explain why 807 pigs should have a bursa on both the plantar and medial aspects of the left leg or indeed why 135 pigs should have a bursa on the medial aspect but no bursae on the lateroplantar or medial aspects. However, these are examples of relatively few pigs only.

Bursae with erosions

Erosions of the dermis overlying the bursae were noted over the plantar or lateroplantar aspect but never over medial bursae if present. These erosions varied in size from small shallow circular lesions 4.6-6 mm in diameter to extremely large granulomatous masses involving the whole bursa. During the survey a total of 125 (0.89%) of pigs were presented with bursal erosions. The distribution of these pigs was examined in relation to small, medium and large farms as already defined and the results are noted in Table 4.

Table 4

Farm size	Pigs with bursal erosions			
	No. of farms	No. of pigs	No. of pigs with erosions	% Affected
Small	46	2163	12	0.55
Medium	47	4052	27	0.67
Large	53	7831	86	1.10
Total	146	14046	125	2.32

The mean number of pigs with bursal erosions submitted per farm in each output category (small,medium and large) was 1.7, 1.5 and 2.6 respectively. As farm size increases there is a clear tendency for the number of pigs with bursal erosions to increase. This might indicate that large farms are more likely to keep pigs in conditions which would lead to bursal erosions. On the other hand, as the ratio of pigs to workers increases it is possible that stockpersons would have less time to remove pigs to hospital accommodation where the lesion could resolve. The correlation between the percentage of pigs from each farm with bursal erosions and the mean bursitis score per farm was examined by regression analysis. There was a significant positive correlation ($p < 0.01$). The farmer producing pigs with the highest prevalence of bursal erosions was a swill feeder and the concrete was extremely abrasive.

Capped hock

A total of 263 (3.58%) males out of 7350 submitted had capped hock of the right, left or both legs, while a total of 132 (1.97%) females out of 6696 submitted were similarly affected. It is difficult to understand why more males than females should be affected. The condition can develop early in the pig's life and has been noted in sucklers. Penny and Hill (1974) noted that capped hock was more prevalent in males than females. A sex effect has also been reported for other leg conditions in particular splayleg which is much more prevalent in males (Skörries, 1975).

The relationship between the prevalence of capped hock and mean bursitis score in farms producing pigs with bursitis in low, medium and high scoring categories was examined (see Table 5)

Table 5: The number (%) of pigs with capped hock in low, medium and high scoring categories

	Farm scoring category			
	Low <1.1	Medium 1.1 - 1.7	High >1.7	
Capped hock	No. of pigs (%)	No. of pigs (%)	No. of pigs (%)	Total (%)
Left leg	10 (0.07)	22 (0.16)	51 (0.36)	83 (0.59)
Right leg	3 (0.02)	19 (0.14)	29 (0.21)	51 (0.36)
Both legs	14 (0.10)	112 (0.80)	135 (0.96)	261 (1.86)
Neither leg	2152 (18.32)	4678 (33.30)	6821 (48.56)	13661 (97.19)
Total	2179 (15.51)	4831 (34.39)	7036 (50.09)	14046 (100.00)

Thus, as the mean farm bursitis score increases the prevalence of capped hock also rises. However, the bias towards the left leg is not easily explained other than by bias in the collection of data. As the pigs move on the line the left hock is viewed first and it is possible that the angle of presentation may have lead to a bias in the subjective assessment of the lesion.

It was noted that when capped hock was present the severity of bursitis in other areas of the hock was markedly reduced. The mean bursitis score for those pigs with capped hock of the left leg, right leg or both legs is noted in Table 6.

Table 6: Pigs with capped hock and mean bursitis score

Capped hock	Mean bursitis score M	F
Left leg	1.079	1.250
Right leg	1.469	1.184
Both legs	0.580	0.644
Neither leg	1.645	1.594

Thus, when capped hock is present on both legs the mean bursitis score in both males and females is lower by a factor of 50%. This would indicate that some pigs sit or lie in a fashion which puts more pressure on the point of the hock compared with other areas of the hock.

Bursae and infection

Samples of fluid were aspirated from recently formed fluid filled bursae from pigs at all stages of development. Fluids were cultured in both mycoplasma media and 5% sheep blood agar. Apart from occasional contaminants no organisms were grown. This has been a universal finding according to other reports. However, bursae may occasionally become contaminated after penetration of the overlying skin has occurred.

Anatomical aspects

Bursae developed on the same areas of the hock irrespective of age, housing or floor type. A combination of X-ray methods and dissection techniques showed that the mid point of plantar bursae lay directly over the plantar aspect of the lower plantar calcaneus while the mid point of lateroplantar bursae lay over the lower lateral aspect of the calcaneus. This is in agreement with other workers. The medial bursae lay over a promontory of the central tarsal bone. This lies above the sesamoid bone. Berner (1990) stated that medial bursae in sows lay over the sesamoid bone. They did not detect medial bursae in 80 finishing pigs.

BURSITIS AND HOUSING

A total of 30 farms consistently producing pigs with high, medium and low bursitis scores were identified and visited. Data regarding the type of floor, the percentage of time spent by the pigs lying on each kind of floor and the stocking density in each housing stage were collected.

Floors were placed into three categories: hard, intermediate and soft, while farms were placed in categories according to mean bursitis scores (high, medium and low).

The mean score per farm group, the percentage time spent on each floor category and the number of farms involved is shown in Table 7.

Table 7: Mean bursitis per farm group and time spent on each floor category

Scoring category	Mean score	No. of farms	% Time/Floor category		
			Hard	Intermediate	Soft
High	2.092	10	96.7	3.3	0
Medium	1.281	10	35.7	54.2	10.1
Low	0.452	10	25.1	25.8	49.1

The data were also examined by regression analyses and there was a significant and positive correlation between bursitis score and floor score. ($p < 0.001$)

Regression equation: $\sqrt{bs} = 0.844 + 0.625\ fs$

bs = bursitis score fs = floor score

As the time spent lying on hard floors increased the bursitis score increased. Although pigs from low scoring farms spent 25% of their time lying on hard floors, this occurred at the beginning of the pig's life when its weight was relatively small.

The stocking density was also calculated for each group of pigs at each housing stage on every farm. The mean stocking density for each group of farms and the mean bursitis score and number of farms involved is shown in Table 8.

Table 8: Farm scoring category and mean bursitis score

Scoring category	Mean stocking density (kg/m^2)	Average bursitis score	No. of farms
High	94.9	2.092	10
Medium	77.1	1.281	10
Low	64.0	0.462	10

Thus the farms producing pigs with higher bursitis scores also tended to have higher stocking rates. Regression analysis showed that there was a good correlation between bursitis score and stocking density over and above floor score. ($p < 0.05$)

Regression equation: $\sqrt{bs} = 0.597 + 0.551 \times fs + 0.00349 \times sd$

bs = bursitis score fs = floor score sd = stocking density

These findings would indicate that heavily stocked pigs might spend more time lying and sitting. Ross & Curtis (1976), in their studies of pig behaviour in relation to space allocation, noted that pigs with greater space allocation spent over a third more time walking and running compared with the same group size more heavily stocked.

Development of bursitis - Farm studies

Data were collected from nine litters of pigs on days 5, 12 and 19 of life. In addition, the weight gain was noted. There was no correlation between weight gain and bursitis score or indeed between bursitis and claw or knee lesions but there was a small but significant correlation between claw lesions and knee necrosis. ($p < 0.05$) These results would support the hypothesis that claw and knee injuries are probably due to friction brought about by rubbing (Smith & Mitchell, 1976) whereas bursitis is probably induced by pressure trauma. Adventitious bursae became visible as early as 5 days of life. Dehairing of the skin always preceded the formation of a bursa.

In another study, piglets were examined at each housing stage from birth to slaughter in four farms (Group A) consistently producing pigs with a high bursitis score and in one farm (Group B) consistently producing pigs with low bursitis scores. The pigs in the first group were housed on hard floors with little bedding whereas the pigs in the fifth farm were reared on deep bedding from birth. The prevalence and severity of bursitis was noted at each housing stage and the results are presented in Table 9.

Table 9: The prevalence and severity of bursitis at each housing stage

		F^a	W^b	W^c	F^d
Group A	Prev.	35.69	50.6	87.7	95.755
N = 182	Sev	0.437	0.800	1.247	2.092
Group B	Prev	0	0	0	9.52
N = 55	Sev	0	0	0	0.083

F^a = Farrowing W^b = Weaner 1 W^c = Weaner 2 F^d = Finishing

Prev. = prevalence Sev. = severity

In two farms in Group A the piglets had higher levels of bursitis at weaning compared with the other two farms (Prev. 62.5% v. 9.23%). The main difference was the use of woven wire mesh and cast iron slats in the farrowing rooms of the two farms where a high prevalence of bursitis was detected whereas in the other two farms, solid concrete floors with some bedding was used in the farrowing houses. The presence of an edge along a slat would seem to induce a greater degree of bursitis. This was also noted by Berner et al., (1990). No bursitis was noted in pigs from the fifth farm until the end of the finishing period. The farmer noted that in the hot weather some pigs were able to burrow down to the concrete near the water bowl where they lay to cool off. Even though litters from the two farms with farrowing pens with some bedding had a markedly lower level of bursitis at weaning, the prevalence and severity of bursitis in these pigs rapidly rose and by weaner stage 2 (approximately 40 kg) the prevalence of bursitis had risen to over 80% in all pigs in Group A and the mean bursitis score to 1.247. Thus, the presence of bedding in the early stages of life would not appear to be beneficial if housing conditions are unsuitable later on in life.

During collection of data at the abattoir it was noted that a few farms submitted pigs with different slap marks and there was a marked difference in the prevalence and severity of bursitis between the pigs in each group from the same farm. On these farms the pigs were apparently reared in the same type of accommodation to approximately 35-40 kg and then randomly split into intensive accommodation or deep strawed courts but fed the same ration.

A visit was made to the four farms and data were collected regarding the prevalence and severity of bursitis at 35-40 kg and then at slaughter. The results are presented in Table 10.

Table 10: The mean bursitis score and the time spent on each floor category

Farm	Floor category birth - 39kg	Floor category 40-90 kg	No. of pigs	Mean bursitis score	% Time H	% Time I	% Time S
A1	Hard	Hard	157	2.14	100	0	0
A2	Hard	Soft	31	0.86	53	0	47
B1	Hard	Hard	184	1.75	100	0	0
B2	Hard	Soft	57	0.59	46	0	54
C1	Int./H	Hard	50	1.73	96	4	0
C2	Int./H	Soft	102	0.38	48	4	48
D1	Int./H	Hard	88	1.45	83	17	0
D2	Int./H	Soft	87	0.32	29	17	54

H = Hard floor I = Intermediate floor S = Soft floor

These data show that, within each farm, those pigs reared on hard floors for most of the time had much higher bursitis scores.

OTHER ASPECTS

Bursitis and footrot

In the wild, nature intended the foot to the the hardwear and the ground to be the softwear. Housing pigs intensively has resulted in the reversal of nature's intentions so that the foot becomes the softwear on concrete or floors of a similar nature. The relationship of bursitis to footrot lesions as described by Penny **et al**., (1963), was examined on a herd basis by counting the number of lesions on the hind claws of pigs at slaughter and comparing with the mean bursitis score for pigs from the same farm. The foot lesions noted were: white line lesion, false sandcrack, heel, sole and toe erosion. The number of pigs examined, number of lesions on the left and right hind feet, mean foot score and mean bursitis score are shown in Table 11.

Table 11

Farm	No. of pigs	No. of claw lesions left	No. of claw lesions right	Mean claw lesions	No. of bursitis score
A	50	35	43	1.56	2.023
B	24	57	56	4.71	1.595
C	43	72	76	3.44	1.825
D	48	42	47	1.85	1.500
E	57	74	100	4.3	1.792
F	31	71	68	4.48	2.862
G	48	108	99	4.31	2.164
H	106	95	134	2.16	2.044
I	68	121	145	3.91	2.000
J	27	57	52	4.04	1.390
K	31	37	38	2.42	1.847
L	74	87	116	2.74	1.449
M	44	5	4	0.02	0.376
N	32	2	7	0.28	0.902
O	36	2	2	0.11	0.377
P	58	52	36	1.52	0.782
Q	30	38	39	2.56	1.203
R	34	39	40	2.32	1.599
S	51	69	70	2.73	1.200
T	43	31	31	1.44	0.190
U	46	28	19	1.02	0.440
V	36	10	8	0.5	0.588
W	35	30	34	1.83	0.905

The data were examined by regression analysis and there was a significant positive correlation between mean footrot score and mean bursitis score. ($p < 0.001$) It was noted that two farms had much higher footscores than was expected from the bursitis score (B & F). Subsequent investigation of these units revealed that both were owned by the same farmer and in both farms pigs were fed whey which resulted in serious erosion of the concrete screed, leaving a very sharp aggregate exposed. Penny **et al.**, (1963) concluded that footrot was mainly due to rough abrasive concrete. Foot lesion scores were lower in pigs from Farm D than expected. This was possibly related to the fact that pigs were housed on straw for several weeks before being finished on a concrete slatted floor. The findings of this study would suggest that hard floors play a role in the development of both bursitis and footrot while hard abrasive floors will have even a greater effect on the severity of footrot.

It is often impossible to examine feet properly at the abattoir and the findings of this study would indicate that the suitability of floors for pigs feet might be indirectly assessed, in the majority of cases, by scoring the hocks for adventitious bursitis.

Bursitis/heritability

Backstrom and Henricsom (1966) concluded that the offspring of Yorkshire boars were more susceptible to bursitis and estimated that the mean heritability in four herds was 0.56. However, their method of analysis would have given inflated heritability estimates due to common environmental effects (Bampton, 1990).

A heritability study was carried out on pigs from a farm used for research purposes. Data collected included sex, tattoo number, bursitis score, identity of sire, identity of dam and date of slaughter. A model was fitted using dam, dam within sire, sex of pig and month of slaughter. Heritability of bursitis was estimated by paternal half sib analysis. Data were collected from 444 males and 541 females from 11 sires. Analysis of variance showed that sex and month of slaughter had no effect on bursitis scores. The heritability was estimated at 0.25, i.e. 25% of the variation in bursitis severity is genetic in origin.

Financial aspects

At the abattoir, bursae are usually trimmed because they are unsightly, while hams may be condemned if bursae are eroded. Data on the number of pigs trimmed at two abattoirs were collected and analysed. At abattoir A, 1815 pigs came from 43 farms while 340 pigs from 11 farms were presented at abattoir B. A note was made of the farm of origin, leg trimmed (left or right), and bursitis score. The data are shown in Table 12.

Table 12: The number (%) of pigs trimmed on the left leg, right leg or both legs in abattoirs A and B.

Site trimmed	Abattoir A No. of pigs (%)	Abattoir B No. of pigs (%)
Left leg	71 (3.91)	19 (5.59)
Right leg	114 (6.28)	19 (5.59)
Both legs	196 (10.80)	70 (20.59)
Neither leg	1434 (79.01)	232 (68.23)
Total	1815 (100.00)	340 (100.00)

The data show that in Abattoir A the right leg was much more likely to be trimmed than the left while in Abattoir B there was no bias. In Abattoir B, the meat inspectors trimmed more legs (approximately 10%) although there was no difference in the severity of bursitis between the two abattoirs. In Abattoir A, trimming was the last task performed by the meat inspector and the right side of the pig was the side facing him as the pig passed away from the end of the platform on which he was standing. All the men involved were right handed. In Abattoir B the three meat inspectors stood at the same point on the line and worked as a team and tended to back each other up on most tasks.

Analyses of deviance showed there was no abattoir effect but there was a significant and positive correlation between the number trimmed and the mean bursitis score. ($p < 0.001$) The analysis also showed a large variation in the number trimmed between batches, irrespective of the bursitis score, especially in abattoir A. This was not surprising since one meat inspector never trimmed a carcase at all, irrespective of the severity of bursitis. When a batch of pigs had a high prevalence of pleurisy with adhesions, pleural stripping was accorded a much higher priority than trimming. When a batch of pigs was due for export more stamps were required on the carcase and there was less time for trimming in this case. Finally, on days when there was a large kill, the percentage of legs trimmed tended to decrease towards the late afternoon as men tired. The pigs were weighed after trimming was carried out, so every carcase on which trimming was carried out had a reduced value. A total of 100 trimmed bursae weighed approximately 1,200 grams. If the lower trimming figure from Abattoir A (equivalent to 16% trimmed on both legs) is taken as representative of the industry as a whole, then approximately 96,611 bursae will be trimmed in Scotland per annum (total kill = 644,410). This represents a loss of 1159.3 kg at a mean value of 103 pence/kg, a total of £1,194.07. Bursitis will also cause economic loss due to partial condemnations associated with bursal erosions, to poorer selection rates of young gilts and boars intended for breeding, to the cost of hospitalisation and treatment and to the cost of those culled because of being unfit for transportation to the abattoir.

DISCUSSION

Adventitious bursitis of the hock is very prevalent in finished pigs in Scotland. Lesions appear on three main sites over the hock joint and also on the point of the hock (capped hock). The disorder is more prevalent in males than females and more prevalent in both sexes in winter compared with summer. This may be associated with colder weather and higher stocking densities. When capped hock is present, the severity of bursitis in the same leg is reduced. This is probably directly related to the way some pigs sit. As farm size increases the prevalence and severity of bursitis increases and this finding also applied to bursal erosions. These findings were supported by a farm housing survey which showed that pigs with severe bursitis spent most of their time on hard floors especially slatted floors. Most of the large farms tended to keep pigs without bedding from birth to slaughter and to keep pigs more densely stocked. Although farm studies showed that bursitis became clinically apparent in suckling pigs, the provision of bedding at that age does not prevent bursitis developing rapidly at a later stage in the pig's life if housed on hard floors.

However, the provision of bedding later in life markedly reduced the prevalence and severity of bursitis if present. Stocking density played a role in the development of bursitis over and above the effect of floor and infectious agents were not involved in the pathogenesis of the lesions. Pigs with high bursitis scores were also likely to have high footrot scores indicating that both conditions have common causal determinants. Bursitis has a heritability of around 0.25. Although bursitis itself does not cause lameness, there are likely to be more lame pigs in those populations with a high prevalence of bursitis because of the correlation with footrot lesions which can lead to infection gaining entry to the claws. Bursitis is also indirectly responsible for economic loss because of tissue trimmed at the abattoir, condemnations of hams associated with bursal erosions and failure of breeding gilts and boars to pass selection tests because of faulty legs.

CONCLUSION

When pigs are housed on hard floors, especially concrete slats, a high proportion will develop adventitious bursae on the hocks. The disorder can be prevented completely by housing pigs on deep bedding. The condition is responsible for financial loss.

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COMPUTERISED MONITORING OF DISEASE AND PRODUCTION IN FARMED ATLANTIC SALMON (*Salmo salar*)

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A collaborative research project has been established between the Irish Salmon Growers' Association (ISGA) and the Veterinary Sciences Division (VSD), Stormont to develop a computerised management and disease information retrieval system for production of farmed Atlantic salmon (*Salmo salar*). The need for such a database is considered as essential in the development of effective control strategies required to minimise the losses in production which have been encountered by the salmon industry following outbreaks of various disease conditions. Pancreas Disease (PD) is regarded as the most serious threat and this disease does form a serious impediment to the economic production of farmed salmon in Ireland (Murphy, 1991b). In 1987, PD affected 73% of Irish marine sites with an estimated cost to the industry of 5-6 million pounds (Branson, 1988).

The VSD has previous experience in developing a similar system for Northern Ireland's broiler industry (McIlroy et al., 1988). This system has been used to elucidate the epidemiology of contact dermatitis in broilers and allowed for control strategies for the condition to be successfully implemented (McIlroy et al., 1987; Bruce et al., 1990). The economic effects of other avian diseases have also been assessed using this system (McIlroy et al., 1989; McIlroy et al., 1992).

The Irish Salmon Industry

Ireland has an annual salmon production of 6,300 tonnes (Anon., 1991). This level of production is relatively small compared to the farmed Scottish salmon production of over 32,300 tonnes in 1990 (Anon., 1992).

Following smoltification, the juvenile salmon are normally transferred from the fresh-water hatcheries to the marine sites in April/May when they may weigh 45-100 grammes. Smolt stocking densities vary between 10-25 smolts per cubic metre. At the grower (post-smolt) stage the salmon may be harvested as grilse early in the following year when they weigh 1-2 kg or harvested between the following autumn and spring at a weight of 2-7 kg. Salmon are very efficient food converters with a food conversion ratio of less than 2. Grading helps to keep uniformity of size within a cage which allows survival of the smaller salmon within groups of cages.

PANCREAS DISEASE (PD)

PD is a disease of unknown aetiology which affects farmed Atlantic salmon during their marine stage of growth, normally in their first year at sea. PD was initially described in Scotland in 1976 (Munro et al., 1984) but the condition is now known to occur in all the major salmon farming countries of Europe as well as in USA (Kent & Elston, 1987; Poppe et al., 1989). Clinically, PD presents itself with a rapid decline in feeding

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along with the salmon congregating in the corners of the cages close to the surface of the water and the appearance of white faecal casts (Munro et al., 1984; Ferguson et al., 1986; Branson, 1988). This leads to weight loss and in severe cases, emaciation and death. Diagnosis of PD is by histological examination of the caecal pancreas (the pancreas in salmon is a diffuse organ with most of the pancreatic tissue being present in the adipose tissue which separates the caeca). The main histopathological lesion present is degeneration and necrosis of the acinar cells of the exocrine pancreas (McVicar, 1987; Murphy, 1991b). The pathology of PD appears to differ between countries. In Irish and Norwegian salmon outbreaks, cardiac and skeletal myopathies are commonly observed along with the pancreatic lesions (Poppe et al., 1989; Murphy, 1991a). These myopathies are rarely seen in Scottish outbreaks (McVicar, 1987) although they have been reported (Ferguson et al., 1986). There is still debate as to whether the myopathies are part of a variation of PD or whether they represent a different syndrome which appears at approximately the same time (Raynard & Houghton, 1991).

Recovery from PD, uncomplicated by other conditions, occurs with variable mortalities (usually under 10%) and takes between three weeks and three months but there is major economic loss caused by the reduction of biomass and the variability in size of the convalescent salmon (Branson, 1988). Salmon which have recovered from PD appear to be resistant to further expression of the disease (McVicar, 1991).

PD has been successfully transmitted to healthy parr and smolts by intraperitoneal injection of pooled kidney homogenates from salmon with early PD lesions (Raynard, 1991). This homogenate had been passed through 0.22 um filters which suggests that the primary cause of the PD is a viral-like agent (Raynard, 1991).

In Ireland, a new condition termed Sudden Death Syndrome (SDS) has been described (Murphy, 1991a). Deaths from SDS occur six to eight weeks after an outbreak of PD with deaths appearing to be associated with periods of exertion eg. feeding, lice treatments. Severe skeletal myopathies are found in mortalities from SDS (Murphy, 1991a). Any association of SDS with PD is as yet unclear.

MATERIALS AND METHODS

The research team involved in the project include an epidemiologist, a biometrican, a fish pathologist and a research student. This indicates the multidisciplinary approach being taken to the project. The initial objective of this project is to identify production, environmental, disease and management parameters which are significant in determining the profitability of salmon farming in Ireland. The second objective is to try and elucidate the mechanisms and/or contributing factors involved in the occurrence of the important diseases of farmed Atlantic salmon.

ISGA Survey

The initial stage of the project is to assess the data which is routinely recorded by salmon producers and to identify those sites which could be used for intensive monitoring. As the first step, a questionnaire was mailed out to all ISGA members. The aims of this questionnaire were:-

a) To gather basic information about each marine site,
b) To evaluate the records kept by different farms,
c) To assess the different management systems,
d) To assess the prevalence of the major disease conditions.

The questionnaire was pretested using four ISGA members. Table 1 summarises the key areas covered by the questionnaire.

Data collection

Respondents to the survey are being followed up by a series of visits. These visits are used to collect data, to double check questionnaire information and to assess the accuracy of data recording. Non-respondents were also visited to see if they would participate in the project. Most of the farms record their production and some managemental data on a variety of computerised spreadsheets and keep manual records of the environmental and disease data. Table 2 gives examples of the type of records kept within each of these categories. Many sites have retrospective records for the last three to four years. The main disadvantage is that the records are stored in different formats which means a lot of time has to be spent interpreting and standardising the data. The other major problem is the location of the salmon farm sites because of their wide dispersion over Ireland.

Computer systems

Records are initially interpreted and standardised using spreadsheet software and a personal computer. The standardised records are then transferred to ORACLE, a relational database which is held on a VAX 6320 mainframe. More sophisticated statistical analyses are carried out using SPSS and GENSTAT.

RESULTS

The response rate to the survey was 53%. The main reasons for non-respondents included farms changing ownership or farms going into receivership. The relatively high response rate, considering the detail of the questionnaire (15 pages), indicates the concern of the salmon producers to their disease problems and their sense of urgency in finding methods of disease control, particularly with regard to PD. From the survey and subsequent contact with ISGA members, permission has been granted to allow access to the records from 13 farms which gives the potential to investigate more than 27 sites.

Initial information from the survey indicates that the most important disease conditions observed by salmon producers are sea lice infestation, Pancreas Disease, Vibriosis, Furunculosis and Sudden Death Syndrome. Table 3 shows the prevalences and mortality ranges experienced for the common diseases of farmed salmon by marine site as indicated by the returned questionnaires for outbreaks in 1990. Figure 1 illustrates disease prevalence in relation to different mortality ranges.

Table 1. Details of the key areas covered by the questionnaire.

Key Area	Main Question Points
Health & Disease	1. Information on sea lice treatments. 2. Pancrease Disease & Sudden Death Syndrome; their occurrence over 1987-1990 and mortality rates. 3. Other disease outbreaks in 1990 and their attributed mortality rates.
Water Quality	1. Potential parameters measured; temperature, dissolved oxygen, salinity, pH, wind speed, suspended solids, ammonia, nitrate, BOD, heavy metals, any other substances. 2. Of those parameters measured, their frequency of measurement, method of measurement and annual minimum and maximum values.
Feedstuffs	1. Sources, feed types and the time period a feedstuff is used over 1990. 2. Methods of feeding, feeding frequency, monitoring of feed, feed storage.
Stock Details	1. Different sources of smolts and the different strains and numbers stocked in 1990. 2. Treatments given to smolts before delivery. 3. Average weights of smolts on delivery.
Cage Design	1. Numbers and types of different cages used. 2. Cage dimensions for each cage type.
General	1. Number of years site has been established. 2. Annual harvest for 1987, 1988 and 1989. 3. Are any trout kept on the site? 4. Grading methods. 5. Degree of predator problems from seals and birds. 6. Management of nets. 7. Distance and direction of nearby fish sites. 8. Staff and equipment resources.

Table 2. Examples of the type of records kept within each category.

Production	Environment	Disease	Management
Mortalities	Temperature	Behaviour	Stocking policy
Growth rate	Salinity	Date of outbreak	Feeding policy
Feed amounts	Ammonia	Lab reports	Vaccination
Salmon strains	Turbidity	Treatments	Fallowing
Origin of smolts	Site factors		

Table 3. Prevalences and mortality ranges of the common diseases of farmed Atlantic salmon in 1990.

Disease	% Sites affected	Mortality Range (%)
Sea Lice Infestation	94.1	0 - 12
Furunculosis	23.5	1 - 5
Vibriosis	82.4	1 - 27
Pancreas Disease	76.5	0 - 45
Sudden Death Syndrome	17.6	35 - 45

Exploratory data analysis

At the end of 1991, exploratory data analysis became possible on one set of farm data. Percentage mortality within a site is used as the parameter for measuring profitable production and initially the period between June and December inclusively during the salmons' first year at sea will be the interval which is to be studied. This removes the complications in mortalities caused by transfer losses and the effects of grading.

Initial analysis has been completed on mortality rates and environmental data from one site over three years. PD was the major disease problem between 1988-1990 on this site although Vibriosis did present a secondary bacterial complication during the PD outbreaks in 1989 and 1990. Losses due to secondary bacterial diseases are not unusual during episodes of PD (Munro et al., 1984; Murphy, 1991b).

Measurements of the percentage mortality and the environmental parameters are studied at two weekly intervals. The environmental measurements were obtained at a depth of ten metres.

In 1988, no statistically significant correlations were found between percentage mortality and any environmental variable. In 1989, statistically significant correlations were found between percentage mortality and coincident fortnightly intervals ($r = 0.53$, $p < 0.05$) and with temperature lagged at one interval ($r = 0.55$, $p < 0.05$) and at two intervals ($r = 0.59$, $p < 0.01$). In 1990, statistically significant correlations were found between percentage mortality and temperature lagged at one interval ($r = 0.53$, $p < 0.05$) and at two intervals ($r = 0.51$, $p < 0.05$). Figure 2 shows the regression relationship between water temperature logged by one month and percentage mortality in 1989.

In 1989 and 1990 there was some evidence of a correlation between the percentage mortality and dissolved oxygen but such correlations were deemed spurious owing to a concomitant negative correlation between water temperature and dissolved oxygen.

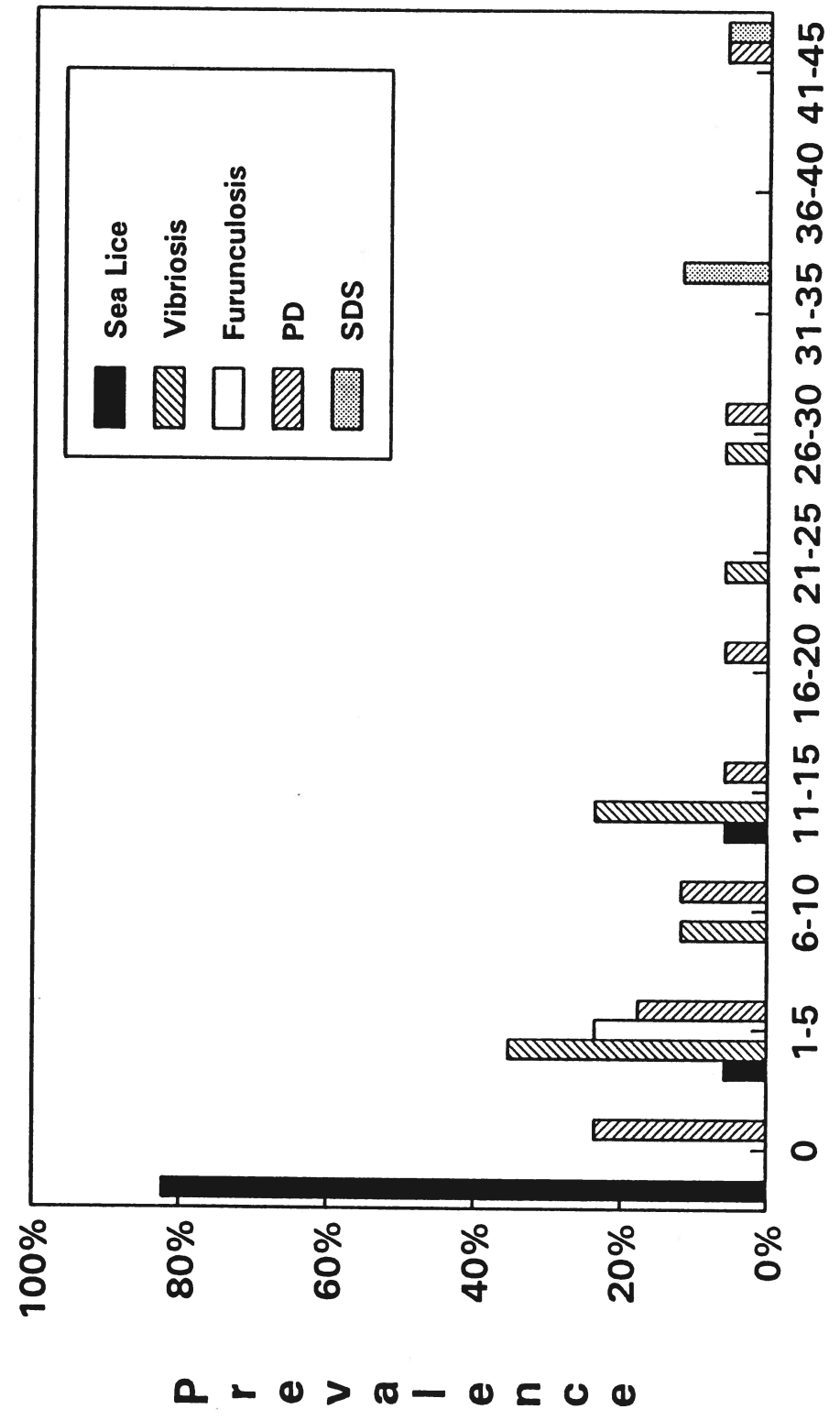

Fig. 1 Prevalences within mortality ranges of the common diseases of farmed Atlantic salmon in Ireland in 1990.

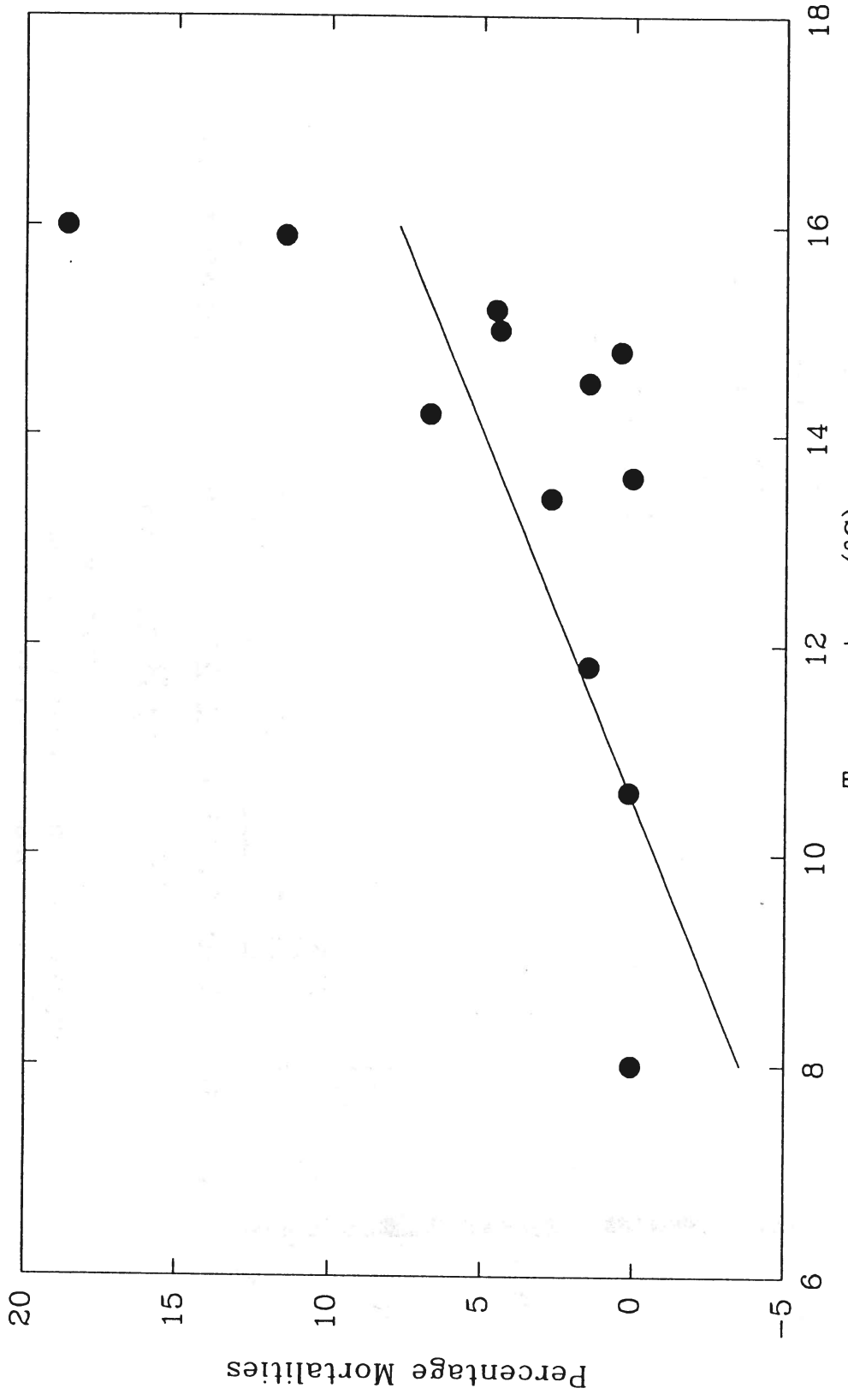

Fig 2. Regression relationship between water temperature lagged by one month and percentage mortality.

DISCUSSION

The results from the survey represent the most accurate disease information available for the Irish salmon industry. From figure 1, it is interesting to note the variations in prevalence and mortality rates of different disease conditions. Sea lice infestation is an almost ubiquitous problem, but because of effective monitoring and control measures, it is rarely a cause of mortality. In comparison, SDS has a relatively low prevalence but is a cause of high mortality rates when it does occur.

Analysis of the data from the site currently under investigation shows a significant correlation between percentage mortalities and water temperature. This can be explained biologically by two main hypothesis. Firstly, increased water temperatures allows for increased speed of replication of infectious agents (Harrison, 1978; Seeley & Van Demark, 1981). It is currently thought that PD is caused by a viral-like agent (Raynard, 1991) and the rate of replication of such an agent is directly related to the metabolic rate of the fish. The metabolic rate of salmon is directly correlated to the water temperature (Laird & Needham, 1988) and so the higher the temperature, the higher the replication rate of the infective particles; this exposes the remainder of the salmon population to a higher infective load. An increase in the dose of infective material containing the agent causing PD has been shown to increase mortality rates in salmon (Raynard, 1991).

Secondly, a more general effect of increased temperatures is the added stress to salmon that may be caused by decreasing the level of dissolved oxygen (Shepherd & Bromage, 1988). This is further complicated by the increased demand for oxygen by the higher metabolic rate of salmon at a higher temperature. This combination of increased water temperature and decreased dissolved oxygen are factors which are recognised as contributing to the occurrence of various infectious diseases of salmon (Laird & Needham, 1988).

CONCLUSIONS

Initial exploratory data analysis using the records from one site has identified water temperature as being associated with the occurrence of PD. It will be possible to investigate this association in more depth when complete datasets have been obtained for all marine sites where PD has occurred. Information from more sites distributed throughout Ireland will also enable comparisons to be made in terms of the four different parameters already discussed. Comparisons of different sites in terms of these parameters will allow for quantification of the multifactorial aspects of PD and the other economically important diseases of farmed Atlantic salmon.

This ongoing study will be of invaluable benefit to the Irish salmon industry once the database has been fully constructed and will form an unique tool in maximising profitable production of farmed Atlantic salmon.

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HAS THE WARBLE FLY PROBLEM GONE AWAY?

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The warble fly is a cattle parasite whose life cycle, briefly, starts in summer as an egg laid on the leg of the host from which a minute larva emerges and burrows through the skin. It migrates through the body of the host and by the following spring forms a visible lump, or warble, on the back. After 4-6 weeks, having reached a length of about 2.5cms, it emerges and pupates in the soil and after 3-5 weeks the adult fly, which resembles a hairy bee, emerges. It then has to find a mate and (if female) find some cattle to lay her eggs on. Two species of cattle warble fly, Hypoderma bovis and H. lineatum, were common in Great Britain although H. bovis was far more numerous (Tarry, 1981).

The most effective control of the parasite is through systemic treatment of the host either with a pour-on organophosphorus preparation or injection with avermectins. This can be done either in Autumn or Spring; in midwinter treatment is dangerous because the resulting larval debris can lead to an adverse reaction. Autumn treatment is more effective than Spring treatment because the smaller and younger larvae are more susceptible.

The economic losses arising from this parasite, the pain and suffering caused to cattle, and the evident feasibility of achieving success led to the start of an eradication campaign in Great Britain in 1978, and it has been clear for some time that for practical purposes the fly is no longer present. Attempts to be more precise about this conclusion lead to some interesting problems, and it is the purpose of this paper to examine them.

HISTORY OF THE ERADICATION CAMPAIGN

The Warble Fly (England and Wales) Order 1978 and the Warble Fly (Scotland) Order 1978 initially required that all cattle found to be warbled were treated with an organophosphorus pour-on preparation in Spring (before the larvae emerged). This requirement, together with the publicity encouraging farmers to examine and to treat their cattle, led to a decline in apparent incidence. In 1981 the requirement became for the whole herd to be treated in spring and again the following autumn in the event of any warbled animal being found, and in 1982 it was made a Notifiable Disease. There were no additional requirements for treatment but notification ensured that treatment could be supervised if staff were available, and around half of all such treatments were supervised. In 1983 an infected area was declared in Anglesey, a small island in North Wales where half the notifications in 1983 had originated. All cattle in the Infected

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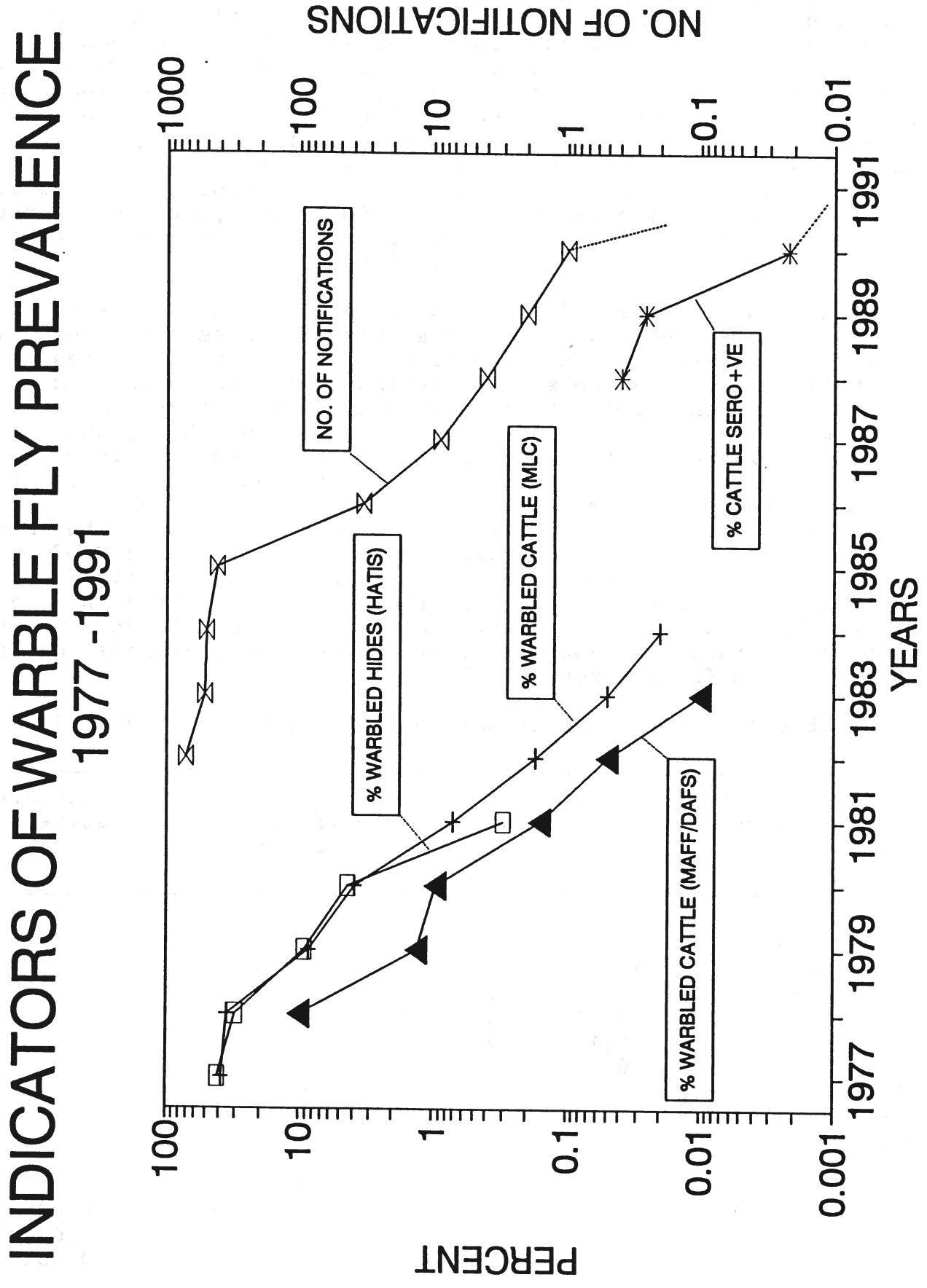
Area were required to be treated during October 1983.

The Infected Area policy was used again in 1984, 1985 and 1986, the areas concerned being defined differently each year, on the basis of notifications arising earlier during the year. In 1987 and subsequent years there were insufficient notifications to justify declaration of any Infected Areas. In spring 1988 following development of a specific test (Sinclair and Wassall, 1983) a serological survey was carried out and where positive reactors were.found the herd and its immediate neighbours were visited, all cattle bled and positives identified. These cattle were then treated immediately. In the following years the survey was repeated, but positive herds were now required to treat all cattle as were neighbours up to 3km distant.

During the course of the campaign various indicators of prevalence have been used and these are summarised in Table 1. Before the start of the campaign in 1978 two sources of information were available; an estimate of the proportion of oxhides with open warble holes provided by the Hides and Allied Trade Improvement Society, each year since the 1960s, and from 1972 an estimate of the proportion of 'fat' cattle visibly or palpably warbled at markets in May of each year produced by the Meat and Livestock Commission (Peters and Melrose, 1985). From 1978 a similar market survey was carried out by veterinary officers of the Ministry of Agriculture, Fisheries and Food and the Department of Agriculture and Fisheries for Scotland, but relating to all cattle in markets from January to June each year; this produced appreciably lower proportions than the MLC survey which concentrated on younger (more susceptible) animals during the peak month for apparent warble infection.

Table 1. Prevalence of warble fly infection, 1977-1991

Year	MLC survey (%)	MAFF/DAFS survey (%)	HATIS (%)	Notifications (Number)	Serological surveys (%)
1977	38.0		40.3		
1978	34.3	10.0	29.9		
1979	8.6	1.34	9.2		
1980	3.9	0.95	4.4		
1981	0.7	0.16	0.3		
1982	0.17	0.05		705	
1983	0.05	0.01		518	
1984	0.02			500	
1985				419	
1986				34	
1987				9	
1988				4	0.039
1989				2	0.026
1990				1	0.0022
1991				0	0


INDICATORS OF WARBLE FLY PREVALENCE
1977 -1991
NO. OF NOTIFICATIONS
1000
100
10
1
0.1
0.01
NO. OF NOTIFICATIONS
% WARBLED HIDES (HATIS)
% WARBLED CATTLE (MLC)
% CATTLE SERO+VE
% WARBLED CATTLE (MAFF/DAFS)
100
10
1
0.1
0.01
0.001
PERCENT
1977
1979
1981
1983
1985
1987
1989
1991
YEARS

All these surveys showed a decline in prevalence immediately the campaign started, which was sustained in subsequent years. They were abandoned as the numbers became too small to be reliably counted; the last one was the MLC survey in 1984. For a time the only quantitative indication of prevalence was the number of notifications. These numbers are not easily interpreted in terms of real underlying rate of infestation; the likelihood of an outbreak being notified will have been variable. In 1985, 66% of the 419 reports were from Ministry staff making farm visits (Tarry, 1987).

In 1988 the first of a series of annual serological surveys was carried out, in spring. The sera were drawn from those submitted to the Central Veterinary Laboratory for brucellosis testing between January and April, and came from throughout England and Wales. The results of these surveys are shown in more detail in Table 2, and are discussed further below. They were reported by Sinclair et al (1989, 1990, 1990) and Tarry et al (1992). In 1991, there were no notifications and 226,659 sera from 8534 herds were examined with no positives found.

Table 2. Serological survey results, 1988-1991

Year	Sera tested	Farms tested	Sera positive	Farms positive	Number sera per positive 100,000
1988	74,502	3,087	29	18	39
1989	152,434	6,175	39	21	26
1990	231,305	9,252	5	5	2.2
1991	226,659	8,534	0	0	0

INTERPRETATION OF SEROLOGICAL SURVEY RESULTS

The usual interpretation of a negative survey is in terms of the maximum prevalence that is consistent with such a result, to an appropriate level of probability, assuming that the sample collected was equivalent to a simple random sample of the population of interest. There are tables that are useful in such cases (Cannon and Roe, 1982) but a simple rule can be applied provided the sample is not a large fraction of the whole population; there is 95 percent certainty that the prevalence was not sufficient to expect three positives in a sample of the size selected. Thus the result of the 1991 survey leads to a maximum prevalence of 3/226659 or 0.00132% of cattle positive.

Similar low prevalences are often quoted as evidence that a disease is completely absent from a population, since such a result is the best that can be provided by a sample survey. The possibility of such a conclusion depends however on an additional

assumption, that is that such a low prevalence is not consistent with the known epidemiology of the disease.

Although warble prevalences are commonly very high when no controls are applied, this is not to say that low numbers are not possible; there must however be some lower limit to the size of a viable population, where the chance of one fly successfully mating with another is reduced by their sparseness. This possibility, of low density leading to extinction, is sometimes called the Allee effect (Southwood, 1981). It may, then, be useful to consider what is the maximum likely number of seropositive cattle consistent with our result; and taking the England and Wales population of cattle and calves as 8.4 million, the number is 111 cattle. If we can continue sampling in subsequent years (as is the intention) and there are no more positives, then having sampled a constant population each year the same limit will apply to the total number of seropositives over all years; and since the serological reaction does not last from one year to the next, while a viable warble fly population has to raise more such reactions each year, the maximum average population will be one half after two years, or one third after three years, of the original 111..

Alternatively, if we consider herds instead of individual cattle, the number included in the negative survey of 1991 was 8,534 out of a population in England and Wales of about 100,000. The likely maximum prevalence is 3/8534, or 0.035%, or 35 herds. Again this will be reduced if repeated in subsequent years.

This leaves, however, two important questions:-

What is the minimum viable population, and
Is the sample anything like a proper random sample?

THE SAMPLING SCHEME

The blood samples examined were taken from those submitted to CVL for testing for brucellosis. All cattle herds have to be tested every two years, and on the occasion of the test all cattle over twelve months old, except dairy cows, are blood sampled. The samples are sent to CVL where they are first screened using the Rose Bengal plate test; positives are kept for further testing. The samples taken for hypodermosis testing were taken from those negative to the screening test, which is normally about ninety five percent of the sample submitted. Samples were taken each day up to the maximum number that could be examined, without any further selection; thus where a herd was included it was generally all members of the herd, with the exception of those under 12 months, dairy cows, and any positive to the brucella screening test.

As far as individual cattle are concerned the sampling scheme clearly cannot be regarded as providing a proper random sample since the type of cattle is constrained, and within those types nearly all the cattle in a herd are selected if any are. Among herds there would not appear to be any bias by area or other

factor, nor any reason to expect neighbouring herds to be other than independent in their chance of selection.

Considered as a herd test there is a problem with the sensitivity of the sampling scheme. Since five percent of samples are not tested because of a positive brucella screening test, it must be assumed that there is only a 0.95 chance of a herd with a single hypodermosis reactor being detected, and many detected herds have included only a single reactor. It is also particularly unfortunate that the brucellosis scheme does not require samples from cattle under 12 months old, since it is the youngest stock that are particularly susceptible to warbles - at least it is well known that eggs laid on young cattle are more likely to produce warbles, although it may not be the case that adult flies seek out younger stock to attack. Further, any stock under about six months old at the time of sampling are unlikely to have been born when flies were active the previous summer.

The chance of a positive herd being detected given that it is included in the survey, might consequently be reduced to 80 or 90 percent. If we assume 80 percent then the maximum likely prevalence or number of herds is simply divided by 0.8 to give 0.044%, or 44 herds.

MINIMUM VIABLE POPULATIONS

As with any parasite population, it is important to be clear about exactly what one wishes to count in order to define population numbers. The number of parasites is not necessarily simply related to the number of parasitised hosts, and the life cycle of the parasite balances enormous multiplication at the start with a high level of mortality during each stage to adulthood. Weintraub (1978) gives a life table for M. bovis which is reproduced in Table 3. This shows how the eggs laid by one female fly, in the average conditions he observed in Alberta, Canada, give rise to 1.5 in the next generation, which allows for a certain amount of further loss due to mate and host finding.

The important stage where mortality is strongly dependent on density, so as to limit large numbers while acting less severely on a sparse population, is the stage internal to the host where immunity seems to be stimulated more effectively by large numbers. Several experiments have shown that a greater proportion of eggs result in warbles when the initial number per individual host is low, and this reduced mortality gives a greater rate of increase in a low population.

There are other biological characteristics which serve to mitigate the danger of extinction when numbers are low. The response of pupae to rising temperatures serves to some extent to synchronise adult emergence in a given locality. Further, according to Weintraub (1978), the adults are attracted to very restricted topographical formations, described as coulees or draws, which provided they exist will clearly enhance the probability of finding a mate.

Table 3. Warble fly life table (Weintraub, 1978)

Stage	No. alive	Mortality cause	Type[a]	No. dying	%
Eggs	200	Infertility	DI	20	10
		Grooming, etc	DI	30	15
		TOTAL		50	25
Internal larvae	150	Invasion	DD	80	53
		Host resistance, migration	DD	54	36
		TOTAL		134	89
Larvae in backs	16	Grooming, etc	DI	7	43
		Infections	DD	1	7
		TOTAL		8	50
Larvae dropping	8.0	Low temperature	DI	1.5	19
Puparia	6.5	Weather, etc	DI	2.3	36
		Predators	DI	1.0	15
		TOTAL		3.3	51
Flies	3.2	Weather, etc	DI	0.2	6
Females	1.5	?		?	?
Generation				197.0	98.5

[a]DI: density independent DD: density dependent

So the parasite is clearly able, and adapted, to survive in low numbers but the question remains of exactly how low, or more particularly how many hosts are likely to be involved and show a measurable serological response. There is also a question of how many herds are likely to be involved; could we have one or two intensive foci without infestation spilling into neighbouring herds, or is it possible for extensive infestation to occur with a number of herds being lightly infested but none heavily so?

There seems to be general agreement that the female fly once mated will not range any further than necessary to find some cattle; these are heavy flies which cannot feed. Having found some cattle she will then lay eggs on several individuals. Three experiments reported by Minar (1984) in which single gravid females were released led to warbles being found on 12, 47 and 11 cattle the next year and it is probable that more had contained larvae, and would have shown a serological reaction if tested.

This leads to an expectation that a population could easily be sustained in a single herd, but a fairly heavy infestation would occur and unless the herd was exceptionally isolated, cases would then be found in neighbouring herds. However efficient the fly may be at finding suitable topographical locations for mating, the possibility of a population in which most matings are of adults originating from separate herds seems remote.

The results of the serological surveys, however, seem to show a different picture.

In 1988 and 1989 the average number of positives in a herd containing any positives was less than two, despite an average of 25 animals tested per herd, and the herds were widely scattered; 9 and 11 counties respectively were involved. In 1990 the five positive samples all came from different herds in different counties. In 1988, but not in subsequent years, 108 herds neighbouring the 18 positive herds were tested; 10 were positive with an average of only 1.7 positive animals, despite nearly 60 animals per herd being tested.

Altogether, including the ten neighbouring herds in 1988, serology has detected 54 herds, but only 90 positive animals between them. In many cases enquiries were made about whether the positive animals had spent the previous summer in the same herd, and we believe that this was usually so. Without cattle movements playing a significant part, the picture of scattered, light infections with no apparent foci is hard to explain. The only plausible possibility, which might owe something to wishful thinking, is that the general level of treatment was high enough for each fly population to have few survivors each year, and to have a significant probability of failing to replace itself. Each year from 1988-1990 the survey showed some of these populations that were still in existence, but all were in fact bound to disappear eventually.

REMOVAL PRESSURES ON THE FLY POPULATION

A simple (perhaps over simple) mathematical model of infectious disease (Richards and Wilesmith, 1989) indicates that the number of cases should increase (or decrease) each year by a fraction equal to the infection rate (new herds infected per infected herd) minus the clear-up rate (proportion of herds becoming uninfected). Inspection of Table 1 indicates that in the early years of the campaign, and again in the last few years, a fractional reduction of about seventy percent has been achieved each year. From 1984 to 1988 no reliable conclusions can be drawn.

The serological survey, covering less than ten percent of herds but with treatment of neighbours where positives are found, cannot be considered as contributing more than about twenty percent to the clear-up rate. It may be that the population is already reduced to the point where its capacity for increase in the absence of control is lowered, or that other influences including the widespread uptake of ivermectin treatment (mainly for helminth control) has provided sufficient additional pressure

to ensure the continuing decline in numbers. These possibilities are currently being examined.

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EPIDEMIOLOGISTS' VIEWS OF ECONOMICS - AN ECONOMIST'S REPLY

K S HOWE*

Over the past decade or so a series of papers on the economics of animal disease has emanated from the Agricultural Economics Unit at Exeter University. A large proportion has been presented at meetings of this Society. A characteristic of these papers which distinguishes them from the many others published in the field of so-called veterinary economics is their concentration on conceptual and theoretical issues as opposed to empirical analysis. Our chosen emphasis reflects conclusions drawn from an ongoing review of such publications which, almost without exception, have a strong empirical bias. Of course, this focus on empirical work is not unexpected because addressing real world problems necessarily involves recourse to the collection and analysis of data. However, a particular feature of most of these studies is the absence of clearly specified economic models which underpin the many empirical estimates presented. To an economist, this is a curious and inexplicable omission.

In trying to understand why the procedures of veterinary economics should be different from any other area of applied economics it was necessary to develop an appreciation of the emerging field of veterinary epidemiology. In itself, the existence of a symposium which couples veterinary epidemiology with economics (namely the International Symposium for Veterinary Epidemiology and Economics, ISVEE) suggested that economic and veterinary considerations may be considered of parallel importance in the study of disease and its effects in animal populations. Perhaps an obvious question that arose concerned the extent to which economics and veterinary epidemiology are, in practice, conceptually distinct areas of enquiry. As the author argues elsewhere (Howe, 1988; 1989), it turns out that economics ought to be regarded as a sub-field of veterinary epidemiology with just the same status as, say, serology, statistics, or mathematical modelling. Arguably, the scope for confusion arises because of the inadequate development of a conceptual basis for veterinary epidemiology, as well the indirect route by which economics came to have a role in veterinary studies.

EPIDEMIOLOGICAL ANALYSIS AND ECONOMICS

Veterinary epidemiology still seems to be widely regarded as simply a particular kind of measurement framework. Evidence in support of this view is the text by Martin et. al. (1987), and the

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choice of name for the sessions called 'Econometric Methods' at the 1991 ISVEE in Ottawa. Certainly papers presented in Ottawa under that heading reported results obtained by the use of econometric techniques, but none of these was concerned with econometric methods in themselves in a way that any econometrician, or economist, would understand.[1] Some papers focused, in its strict sense, on economic aspects of disease, and others on the financial consequences of diseases and their control. While there were exceptions, often the studies reported were constructed almost as though economic aspects were a by-product of other scientific concerns. The exceptions, in which the theoretical framework was clearly specified (for example Berentson et. al., forthcoming), served to confirm the earlier observation that the analysis of economic problems in veterinary epidemiology seldom begin with an explicit underlying economic model.[2]

Less tangible evidence that epidemiologists are preoccupied with measurement is the periodic observation by some members of this Society that numbers are conspicuous by their absence from many Exeter papers. Leaving aside the matter of the choice of emphasis which has been mentioned, these people are genuinely perplexed by our unwillingness to resort to simple accounting arithmetic to provide, in particular, estimates of the so-called costs of disease, an approach beset with pitfalls as we have repeatedly pointed out. No doubt a reluctance to understand that economic analysis is not synonymous with simple accounting is explained, at least in part, by the fact that such people have no formal training in economics. In common with many others so deprived, it is easy enough to be persuaded of the fallacy that economics really is as simple as that.[3] Conceivably, this outlook is also responsible for encouraging the idea that economic research is undemanding of time and other resources. For example, it was with some difficulty that the Executive Committee was persuaded that empirical investigation of economic issues raised at last year's Conference in relation to animal welfare could not be easily achieved as the basis for a paper this time. Of course people are understandably frustrated that important questions cannot be answered quickly, but it is not easy to see why, say, it is frequently expected that research in the veterinary sciences may be expensive and take years while economic results can be obtained virtually for nothing and almost overnight. Clearly, something is being misunderstood.

It may be that our attempts to inform and persuade non-economist colleagues of the true place and importance of economics in veterinary epidemiology have misfired. By attempting to build out from veterinary scientists' perceptions about disease in animal populations, and by simplifying economic

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1 "Econometrics uses statistical methods after adapting them to the problems of *economic* life. These adapted statistical methods are called econometric methods." (Koutsoyiannis, 1977, emphasis added.) This statement makes it clear that economic relationships are being explicitly quantified, not epidemiological or anything else.

2 "A model is a simplified representation of a real situation. It includes the main features of the real situation which it represents. A model implies abstraction from reality which is achieved by a set of meaningful and consistent assumptions, which aim at the simplification of the phenomenon or behavioural pattern that the model is designed to study. The degree of abstraction from reality depends on the purpose for which the model is constructed." (Koutsoyiannis, 1979, page 3). Note that the model has no empirical content, i.e. it is independent of data, although commonly in economics it is expressed mathematically.

3 This supposition is, of course, reinforced daily by common experience of what people incorrectly think of as economics. After all, most of us work in exchange for money, borrow and/or lend, pay taxes, receive subsidies, invest and make provision for children and old age. As a result, sooner or later we have to do some personal accounting, if only to keep our financial situation under review or the tax inspector at bay. This does not make as all experts in accountancy (which it is), still less economics (which it is not), any more that knowing how to administer a dog powder qualifies us as vets.

relationships, we may only have reinforced existing prejudices. In other words, we may have confirmed the misconception that economics really is a simple adjunct to epidemiology as many believe but, for all that, we are still unable to produce any useful numerical results. This paper is intended, therefore, as a somewhat different approach towards correcting misconceptions about the nature and scope of economic analysis in the present context.

THE CENTRAL ROLE OF ECONOMICS

In a particular sense, this paper is more assertive about the role of economics than Exeter papers may have been before. For example, a fundamental assertion is that many problems of animal disease and its control, certainly those concerning farm livestock, are not primarily veterinary problems at all. Rather, they are clearly economic problems which veterinarians may help to solve because, like it or not, our concern for the health and welfare of farm animals is because their well-being affects us, and economics is all about the well-being of people.[4] In short, assessing the economic repercussions of disease is the first concern. Only then can judgements be made about the nature and extent of veterinary intervention as the provider of necessary technical support to deal with disease.[5] Presumably every profit oriented farmer makes such an assessment in attending to his personal interests though sometimes, as in the case of any virulent infectious disease, the decision about what to do is taken out of his hands by constraints imposed by law. This is because private actions often have social consequences or, to put it in economists' language, decisions which bring individual private benefits may impose wider social costs. For example, without special provision for compensation it is in the interests of a dairy farmer to sell a cow suspected of foot and mouth infection before clinical signs appear. Compensation payments are made out of the public purse to remove this incentive, so to protect other farmers and, ultimately, consumers who would pay higher food prices in the face of output losses from significant disease spread.[6] But whereas straightforward accounting is sufficient to analyse the *financial* implications of disease, this tells us nothing useful about the impacts on the well-being of society as a whole. For this *economic* analysis is needed, because economics provides a rigorous framework for making objective assessments of the consequences of any actions which affect resource use on the well-being of different groups of people.

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4 This is not the observation of a callous economist. Self-evidently, we choose to exploit animals as an economic resource for human benefit, whether as meat or for what they produce as livestock. Healthy animals are more productive, which is equivalent to saying that resources are used more efficiently. Even when we are (quite properly) concerned for what we call animal welfare, what is considered to be acceptable practice is wholly determined by people in the light of how *we* interpret the observed behaviour of our fellow animals given our own experience and capacity for moral judgements. No other animal is capable of directly communicating its preferences to us.

5 It may be protested that commonly there is insufficient time to wait for the results of economic analysis before veterinary intervention is needed. In any event, relevant data are likely to be unavailable in any novel situation. This makes a difference to the practice, but not the principle. Whenever resources are committed to disease control without empirical estimates for the likely net benefits, it is implicit that these expected net benefits are a) positive and b) of a magnitude reflected by the urgency and scale on which intervention takes place. The UK response to BSE illustrates this principle at work, even though the underlying economic model is not made explicit.

6 Or, as in the case of BSE, to insure people against the risk of a shortened and debilitated life if they, too, should contract the disease.

This applies equally to society as a whole, to particular subgroups of society (e.g. farmers, consumers, veterinarians, university teachers), down to people as individuals.

Possibly this latter statement holds the clue as to why some veterinary epidemiologists continue to be confused about economics, although they above all should be well qualified to recognise the origins of their problem. The clue is that economics is concerned with the well-being of the human *population* classified into various groups at different levels of aggregation. The individual person is not the only, still less most important, unit of observation. Perhaps some epidemiologists trained originally in clinical veterinary science are still the unwitting captives of their old conceptual framework. Try as they may, they are unable to escape the notion that, in the last analysis, the really important unit of observation is the individual animal.[7] While the herd or flock on a farm is recognised as a valid population for study, this exists as a collection of individuals for whom, kept in close proximity, special problems arise in their susceptibility to disease. Further, while disease is also a problem in national animal populations, conceptualising this as a phenomenon which has a still higher level of complexity than can be understood only by reference to individual animals poses severe problems for those trained to focus on the specific case. Above all, it requires a degree of *abstraction* from the particulars of the observable world which may be disconcerting for some empirical scientists.

No doubt this argument may be overstated, but any tendency (albeit subconscious) always to begin by thinking in terms of an individual animal instead of a population contains potential hazards for the way in which epidemiologists' may interpret the economic effects of disease. This is because key economic variables which are validly regarded as constant in relation to the individual animal, herd, or flock commonly change when disease afflicts a much larger aggregate unit. What is more, many of the most pressing concerns in relation to animal health nowadays relate to national and even pan-national livestock populations.[8] Of course, early 'economic' analysis of disease commonly focused on the herd or flock as the basic unit, and still does.[9] This is entirely appropriate in context, but in the same way that epidemiological models designed to address individual herd problems cannot be applied to the study of national livestock populations without modification, correspondingly neither can farm or herd-level economic models be easily generalised for application to problems with national and even international economic consequences. For example, if nothing else some relationship must be included to allow for price changes consequent on major changes in production and trade which result from disease. Such price adjustments are never a problem when disease effects are confined to animals on an individual farm.[10]

One other observation is in order. It is well known that veterinary economics (or the economics of animal health or disease, as some prefer), resulted from problem-solving veterinary scientists perceiving

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7 Of course, this is a characteristic which they recognise in colleagues reluctant to be persuaded of the importance of epidemiology as a key component in veterinary education.

8 Consider, for example, the implications of unrestricted trade under the terms of the Single European Act for the future health status of animal populations in the European Community.

9 As explained elsewhere (Howe, 1989 page 66) the herd or flock is typically the smallest unit of economic interest.

10 This is because farming approximates to the market structure known as 'perfect competition,' but the same convenient outcome is not invariably true for other industries which have types of market structure which need not detain us here. The effects of farm price support also may be an important consideration.

that in many circumstances their activities have an economic dimension. In recent years, not only are more veterinarians emerging as epidemiologists, but often they have acquired a formal grounding in economics. It is to be hoped, therefore, and indeed expected, that in problem contexts where the primary focus is economic, quantitative analysis in epidemiology will be based on explicit models which are well-founded in economic theory. Only then is it valid to specify the econometric methods appropriate to the empirical analysis, and to associate these with epidemiological techniques. Too frequently in the past, economic analysis has been 'driven' by quantitative epidemiological modelling in the traditional sense, with economic analysis treated as a largely supplementary concern. In other words, it has to be remembered that for economic problem analysis in epidemiology, the economic framework *always* comes first.

MEASURING THE EFFECTS OF ANIMAL DISEASE ON HUMAN WELFARE

To illustrate why economics is such a powerful framework for analysing the effects of animal disease on people's well-being we focus on a national population. This perspective has three important advantages. First, it diverts attention away from the individual herd or flock which is such a recurrent feature of epidemiological studies. Second, it forces thereby a degree of abstraction which is essential to illustrate how complex problems can be reduced to a few elements as a foundation for economic analysis. Third, it lends scope for illustrating in a simple way the kind of problems which can occur in applied economics analysis. The purpose is to set out a framework which, it is hoped, will confront veterinary epidemiologists with territory unfamiliar to them but which comes from the core of economics. It must be stressed at the outset, however, that what follows is not new even in veterinary economics, though applications (e.g. Amosson et al., 1982; Jetter and Klein, 1984; Power and Warwick, 1984) are scarce enough to justify setting out the basic framework in more detail here.

The model which follows makes extensive use of concepts from 'welfare economics.' This has nothing to do with unemployment benefits, food stamps, or hospital treatment on the national health. The term 'welfare' has become established in the jargon of economics as referring to people's well-being in the sense used above. It so happens that, given information about how consumers and producers respond to prices, it is possible to get measures of these so-called welfare effects and how they are altered by any factors which change market conditions. Usually, consumers buy more of something when its price falls, whereas producers will sell more only when they can get higher prices. The outcome of this behaviour is shown in Figure 1. When the relationship between quantities consumed and price is plotted we obtain a *demand curve* and, correspondingly, the relationship between quantities sold and price gives a *supply curve.* This simple supply and demand diagram will be known to anyone who has encountered economics at its most rudimentary level.

Now let us imagine that the situation (or 'market') portrayed relates to a national population of farm livestock. It is of no concern which specifically, nor even whether the product of those livestock which is sold is milk, meat, eggs, wool, or something more exotic, because the same economic principles apply in every case. The point where the curves intersect is particularly significant. Here, everyone is content because everything is sold at a price which satisfies both livestock farmers and the consumers of their products. Anywhere else, and either consumers want more than is produced (prices below P_e) or production exceeds consumption (prices above P_e). This signals a disequilibrium which causes adjustments which cease only when *equilibrium* P_eQ_e is restored.[11]

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11 Note that there is no mention of price support for farm products in this analysis. Such government intervention is intended deliberately to distort the natural state of market operations, and so analysing the consequences of free market adjustments always sets the benchmark against which interventionist policies can, if necessary, be appraised.

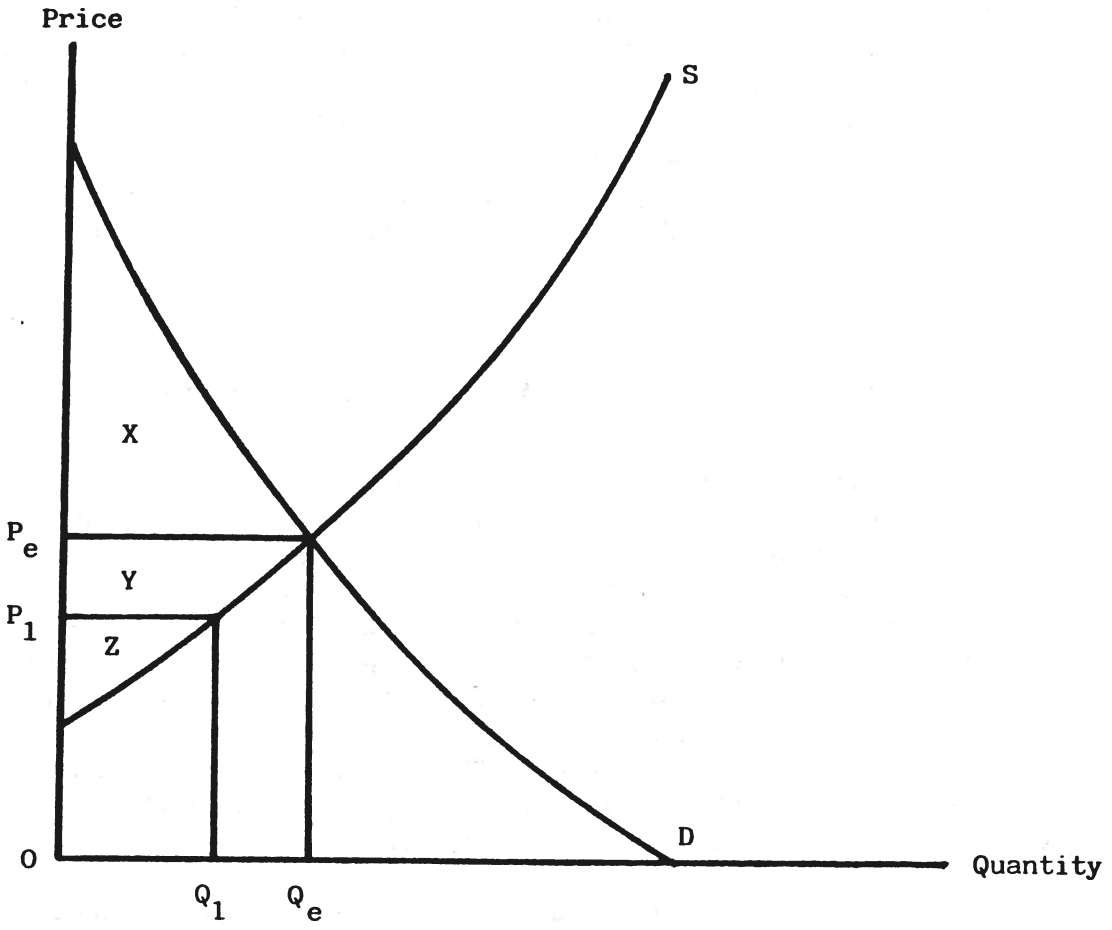

Figure 1. Consumer and producer surpluses before implementing a disease control programme

The area between the supply and demand curves to the left of their point of intersection has a very important interpretation. It provides information about some of the welfare effects in which we are interested. For instance, the supply curve tells us that some livestock farmers would willingly have produced in return for prices below P_e. To give an example, in Figure 1 the production of OQ_1 units of livestock output, say, would have come about even for a price as low as P_1. In practice, all of those units of output which comprise the total of OQ_1 sell for price P_e. Because the market determined unit price of any commodity is a valuation, we can see that some farmers actually obtain more total value (or benefit) from the sale of their livestock products than they might necessarily have sought or expected. In other words, they obtain a kind of economic surplus. To be precise this surplus equals P_e - P_1, not on the *total* production OQ_1 but on the *marginal* unit of output at Q_1. If we add up the surpluses associated with all other units of output between the origin, O, and equilibrium output Q_e, the total economic surplus is given by area Y+Z in Figure 1. This total area measures what, for fairly obvious reasons, is called the *producer surplus*. By analogy, *consumer surplus* is equal to area X. All consumers pay P_e for each unit of livestock product, but some would willingly pay more if supplies were less abundant. They have no need to in the circumstances described, and so they benefit from getting their livestock products more cheaply than otherwise. These people, too, are better off than they might have been.[12]

The reduction (or introduction) of disease in a livestock population alters both the magnitudes and distribution of these surpluses. Remember that the surpluses are measures of people's well-being, in this example confined to only two groups in society, the producers and consumers of livestock products.[13] To illustrate the impact of animal disease on these people we consider in detail only the effects of a reduction in disease, although other possibilities are briefly discussed below. Clearly, the extent to which disease is controlled is an important consideration in practice e.g. whether control is partial or there is full eradication. However, such empirical considerations make no difference to the underlying theory.

An economic model of disease control

The effective control of animal disease increases the productivity of resources in the affected livestock population. In other words, output is increased from any given quantity of inputs.[14] The outcome is to shift the supply curve for livestock products to the right, i.e. farmers are able to produce more at whatever is the going price. This is illustrated in Figure 2, and the welfare consequences can be summarised as follows:

	Gain	Loss	Net
Producers	I + J + K	F + I	J + K - F
Consumers	F + G + H	——	F + G + H
Society	(F + G + H + I + J + K)	- (F + I) =	(J + K + G + H)

Notice that not only is it possible to identify the net effects on producers and consumers respectively, but it is also possible to summarise the consequences for society as a whole i.e. for people irrespective of whether they are producers, consumers or, of course, both. Evidently, as shown here the control of animal disease is beneficial all-round.[15] However, there are other considerations, not least the need to quantify the relevant areas in Figure 2.

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12 McInerney (1987) page 52 expands on such valuation issues in relation to a demand curve as part of his discussion on valuing output losses.

13 Sometimes taxpayers are also identified as a group conceptually distinct from producers and consumers e.g. when analysing the effects of price support for farm products.

14 This is also an outcome of technological change in general, and for that reason the same analytical framework is applied here. See, for example, Fishel (1971), Arndt et. al. (1977), and Howe (forthcoming).

15 Note that this is true even when agricultural policies lead to excess production.

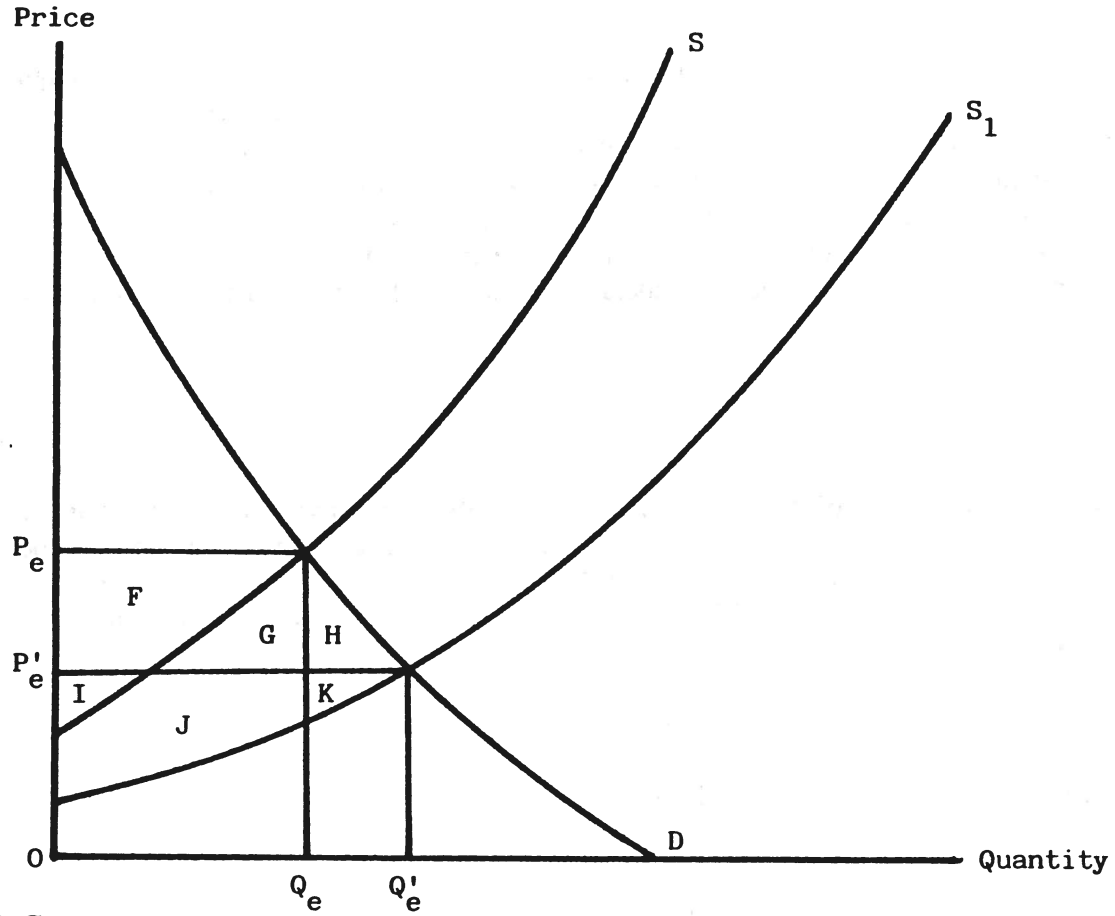

Figure 2. Consumer and producer surpluses after implementing a disease control programme

Measurement problems

Econometric methods have an indispensable role in estimating the relationships necessary to measure the welfare effects of animal disease control. It turns out that the mathematics of calculating the magnitudes of the surpluses, which are expressed in money terms, hinge on obtaining estimates for a) the price elasticities of supply and demand[16] for the livestock product, b) the percentage increase in production attributable to disease control, and c) the new market price and quantity bought and sold after disease control. Price elasticities are normally obtained from first estimating the supply and demand functions, a process which is anything but simple.[17] Obviously, the technical effectiveness of measures implemented for disease control is reflected in the magnitude of the rightward shift in the supply curve. Hence it is a combination of *economic* and *technical* information which makes it possible to evaluate how people are affected by animal disease and its control. The technical information will be largely the product of veterinary science and, especially, epidemiological modelling in the traditional sense. But, to stress an earlier argument, it is the economic model which is informed by technical information when

16 The percentage changes in supply and demand, both with respect to the percentage change in price.

17 Figures 1 and 2 might suggest that all that is necessary is to collect data on market prices and quantities traded, and then estimate a regression equation. But is what is estimated a supply function, a demand function, or some of both? See Koutsoyiannis (1977) chapter 15 or other standard econometrics texts for enlightenment on this 'identification problem.'

estimating the economic effects of disease, and not vice versa. It cannot be expected that economists can somehow conjure economic information from epidemiological studies which were not, at the outset, designed to provide it. Economic analysis poses enough problems in itself.

Further considerations

It should be obvious that the economic model is equally valid for setting out the criteria for evaluating the consequences of introducing disease to a livestock population formerly free from infection. In relation to Figure 2 it is as though S_1 shifts back to S. Moreover, disease can also affect the demand for livestock products. For example, in the UK during recent years both salmonella enteritidis in the case of eggs and BSE in beef have induced marked slumps in demand as a result of consumer scares. The effect in terms of Figure 1 (or 2) is to shift the demand curve to the left. Exploring the implications for economic welfare is left as an exercise for the interested reader!

It should also be remembered that the development and implementation of the means for disease control themselves give rise to outlays which must be included in a comprehensive assessment of their net economic worth. Also, in view of the foregoing discussion it hardly needs to be re-emphasised that it is not only farmers who are the recipients of the benefits from resources expended on improved animal health. Indeed, in the developed economies of the world it is generally consumers who accrue the greater share of the welfare gains arising from productivity improvements in agriculture. In relation to Figure 2 this is because the change in consumer surplus given by (F + G + H) is always positive, while the corresponding change in producer surplus, area (J + K - F), can be positive or negative depending on the relative magnitudes of (J + K) and F. This places an interesting perspective on the notion that veterinarians help control farm animal disease for the benefit of farmers and their animals. In practice, the nature of the economic relationships in developed economies is such that invariably their contribution is more likely to benefit consumers.

This example helps to illustrate a crucial point. It is that judgements about whose interests, or well-being, in society should be given more weight than someone else's is not something that economists are equipped to answer. It is not possible to say whether the distribution of benefits given by the calculated values of (F + G + H) and (J + K - F) is desirable or not. Economic analysis provides only *information* on which *decisions* can be based. It has a vital role in making explicit what is often left obscure and implicit, and in quantifying the consequences of policies scientifically and objectively. Economists have opinions about what is desirable or undesirable but only as private citizens, even though this is too often forgotten (especially by economists!) But the same is true of veterinary scientists who, for example, may extol the virtues of particular campaigns for disease control based on their own list of priorities, desire for job security, or even ill-founded estimates of the costs of disease. They in turn provide information for decisions which affect the well-being of animals and, therefore, of people. It is our political institutions, in the broadest sense, which are constructed to synthesise a wide range of information as a basis for formulating policies and implementing decisions. Such activities include making judgements about the desirability or otherwise of certain actions based, not least, on our human capacity to exercise moral choice. In this process questions relating to animal disease and its control are no exception. Commonly, economists and veterinarians are part of this political process, but both should remain constantly alert to the important distinction between the judgements they make based on personal values and opinions and the information they provide as practitioners of a scientific discipline.

CONCLUSIONS

The stimulus for this paper was a sense that, despite considerable efforts over the past ten years or so, too many people in the field of veterinary epidemiology still have not grasped either a) the substance of what economic analysis is really about, or b) its central role in many areas of veterinary epidemiology. It is neither a peripheral discipline nor one which is any less demanding of resources or intellect than any other constituent discipline of epidemiology.

In a keynote paper to the Ottawa ISVEE, Tim Carpenter (forthcoming) refers to a recent tendency for economic analyses to be dependent on well-designed epidemiological studies now that rudimentary 'price times quantity' calculations are less acceptable. It might have been interjected that even if the approach was considered to be acceptable, more often than not it was incorrect. Be that as it may, Carpenter observes that in addition to animal health economic analyses benefitting from modern epidemiological techniques, econometric methods may prove essential in epidemiological studies. This, above all, summarises what is wrong with veterinary economics. As has been argued above, economic analysis must *always* be founded on an economic model of the phenomenon under investigation. It cannot be 'tacked on' to an epidemiological model, or anything else. Also, econometric models *will* prove essential in epidemiological studies but, again, only when their application is soundly based on economic concepts and principles.

In the last analysis perhaps it is the absence of a well-developed conceptual basis for epidemiology which, more than anything else, explains many epidemiologists' difficulty with economic ideas. Certainly economics is decades ahead of epidemiology in its conceptual development. The model set out here is intended to emphasise that fact, to give further encouragement for epidemiologists to consider the still largely unexploited contribution of economics in epidemiology, and maybe as a stimulus to the development of a corresponding conceptual basis for epidemiology which is so essential to its further progress as a framework for the analysis of empirical problems.

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EPIDEMIOLOGY OF BHV1 INFECTION IN CATTLE BREEDING HERDS IN NORFOLK

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Bovine herpesvirus 1 (BHV1) has a worldwide geographical distribution and is responsible for a broad spectrum of disease manifestations including infectious bovine rhinotracheitis (IBR) and infectious pustular vulvovaginitis/infectious pustular balanoposthitis (IPV/IPB) (Wyler et al, 1989); infection can also be mild and inapparent (Kahrs, 1977). In common with other alphaherpesviruses, BHV1 is characterised by the ability to establish latent infection, mainly in ganglion cells (Studdert, 1989).

The concept of BHV1 latency dictates that after recovering from acute infection, cattle probably remain a potential source of virus for life. Although many studies have shown that reactivation and shedding of latent virus can be induced experimentally, particularly by synthetic corticosteroid injections (Sheffy & Davies, 1972), the extent to which this occurs naturally under field conditions, leading to new infection, is not known. The cross-sectional studies described here utilise the results of whole-herd serological screening tests undertaken in breeding herds in Norfolk to examine the epidemiology of subclinical BHV1 infection with particular reference to the rate of virus transmission amongst susceptible cattle.

MATERIALS AND METHODS

Cattle Health Scheme herds

In April 1987, the State Veterinary Service introduced the Cattle Health Scheme (CHS) for Great Britain (ADAS, 1987). This superseded the Enzootic Bovine Leucosis (EBL) Attested Herd Scheme (Roberts & Bushnell, 1982) and also offered an IBR monitoring programme which gave farmers the opportunity to carry out serological testing for BHV1 and to eradicate the infection from their herds where appropriate.

Sixty-three breeding herds in Norfolk joined the CHS to become EBL attested during the four year period between March 1987 and March 1991. A preliminary questionnaire was completed at the initial visit to each farm, at which the author was accompanied by the owner's veterinary surgeon. Details recorded included: herd size (number of cattle aged two years or more), herd type (dairy or beef suckler), breed, status (pedigree or non-pedigree/commercial), replacement policy (main sources and numbers purchased during the previous 10 years), general management practices and disease history.

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Owners were encouraged to have some, or all, of their cattle examined for serological evidence of BHV1 infection when they were tested for EBL, provided the herd had no recent clinical history of IBR (or IPV/IPB) or IBR vaccination (which would have made it virtually impossible to interpret serological findings). Seven herds were thereby excluded from the investigations: in three the owner declined to undertake any serological testing for BHV1 and four had a history of IBR and had vaccinated during the previous two years. One dairy herd that had experienced epidemic IBR in 1981 and been vaccinated with "Tracherine" (Smith Kline Animal Health) was included because there was no history of revaccination or clinical recrudescence.

The 23 dairy herds in the study population had all been established for at least 20 years and were of pedigree status (20 herds were Holstein/Friesian and three were Ayrshire). Most of the 33 suckler herds had been assembled during the previous 10 years and all but one contained solely or predominantly pedigree cattle. The main suckler breeds represented were: Simmental (10 herds), Charolais (four herds), Blonde d'Aquitaine (four herds), Limousin (three herds), Salers (two herds), and one herd each of: Aberdeen Angus, South Devon, Bazardais, Longhorn, British White, Murray Grey, Highland, Belgian Blue, Shorthorn and Hereford. The systems of husbandry and management were essentially conventional but, being high quality pedigree herds, the sale of breeding stock and regular exhibition at agricultural shows featured prominently in most enterprises.

Serological testing

All cattle, including calves, were blood sampled in 22 herds (10 dairy, 12 suckler): the actual number of calves sampled in these herds depended on the time of year of the test in relation to the calving pattern. Adult cattle only (≥two years) were tested in 31 herds (10 dairy, 21 suckler) and in four dairy herds testing was limited to a sufficient number of adult cattle to detect a 10% level of reactors with a 95% confidence (Cannon & Roe, 1982).

An enzyme-linked immunosorbent assay (ELISA) technique (Edwards et al, 1986) was used to examine sera for BHV1 antibodies. When the CHS was first introduced, cattle were deemed seropositive ("reactors") at optical density (OD) values of >0.1 using a serum dilution of 1/50, but an inconclusive reactor (IR) category (OD 0.10 - 0.19), which required resampling, was subsequently introduced in April 1989 to cope with some inconsistent results. In 1990, the 24 hour serum neutralisation test (SNT) (Edwards et al, 1986) was adopted as the decisive test for IRs that could not be clarified by ELISA: SNT titres of ≥1/2 were classed as positive. Reagent concentrations were altered in October 1989 resulting in a change in the OD range for IRs to 0.15 - 0.25, although the sensitivity of the test remained the same.

Collation and analysis of data

The OD values for each animal tested were expressed as either seropositive or seronegative and recorded with their ear tag or freeze

brand number, sex, age, source (homebred or purchased) and any individual vaccination history (if known).

Herds were coded D (Dairy) or S (Suckler) and numbered sequentially according to the date of the blood test. The serological results were tabulated and also displayed graphically to show the distribution of BHV1 antibodies according to herd identity, herd type (D or S), age and whether cattle were homebred or purchased. Herds were classified according to antibody prevalence and the apparent rate of seroconversion amongst susceptible cattle.

Results were analysed using standard statistical methods (Dunn, 1967); mean values, standard deviations (SD) and standard errors (SE) were calculated where appropriate. Differences in antibody prevalence between dairy and suckler herds were compared using the chi-square test. Correlation coefficients (r) were used to examine the association between the number of reactors and: herd size, number of cattle purchased in the previous 10 years and number of purchased cattle currently in the herd. The association between reactors and purchase was further examined by fitting a generalised linear model (binomial error, logit link) with Genstat 5 (1987), the linear predictor consisting of terms herds and homebred/purchase.

After the test results were known, herd managers were contacted by telephone to discuss the significance of the findings. In herds with a low seroprevalence, details of the movement history (eg communal marsh grazing, attendance at agricultural shows and temporary residence in other herds) of individual reactors and the length of time they had been in the herd were recorded. Where seropositive calves up to nine month old were known to have sucked seropositive dams, they were assumed to have acquired maternally derived (colostral) antibodies rather than infection.

RESULTS

Antibody prevalence according to type and size of herd

Sera from a total of 4,219 cattle (3,201 dairy, 1,018 suckler) aged ≥two years were examined for BHV1 antibodies: 639 (15.1%) were positive. Herd sizes and the number and proportion of reactors in dairy and suckler herds are shown in Tables 1 and 2. The proportion (14.6%) of reactors in dairy cattle was not significantly different to the proportion (16.8%) of reactors in sucklers (chi-square = 2.84, $p>0.5$). There was a significant correlation ($r=0.05$, $p<.05$) between the number of reactors and herd size in suckler herds but not in dairy herds.

There were no reactors in five (21.7%) of the 23 dairy herds and 11 (33.3%) of the 33 suckler herds (chi-square = 0.90, $p>.05$). Of the remaining dairy herds, 14 held 20% or fewer reactors but the other four (D3, D16, D20, D21) each contained more than 60% reactors. Fifteen suckler herds contained 20% or fewer reactors; only one herd (S27) had a seroprevalence of more than 60% but in two others (S19, S20) it exceeded 40%. The frequency distribution for the proportion of reactors in all herds is summarised in Fig. 1.

Table 1 - Prevalence of BHV1 reactors in dairy herds

Herd	Month/Year of test	Cattle aged ≥2 years No	+	%
D1	3/87	227	0	0
D2	3/87	*60 (95)	5	8.3
D3	4/87	136	97	71.3
D4	5/87	*26 (136)	5	19.2
D5	10/87	254	14	5.5
D6	10/87	189	0	0
D7	1/88	133	18	13.5
D8	4/88	154	6	3.9
D9	7/88	123	6	4.9
D10	11/88	114	0	0
D11	5/89	117	1	0.9
D12	11/89	*30 (161)	0	0
■D13	12/89	117	12	10.3
D14	1/90	140	2	1.4
D15	3/90	176	7	4.0
D16	3/90	*28 (200)	25	89.3
D17	3/90	260	19	7.3
D18	5/90	121	7	5.8
D19	9/90	52	0	0
D20	2/91	134	84	62.6
D21	2/91	147	92	62.5
D22	2/91	196	39	19.9
D23	3/91	267	29	10.9
Totals	3/87 - 3/91	3201	468	14.6

No Number of cattle tested for BHV1 antibodies
\+ Number of reactors
% Percentage of reactors
* Statistical screening only (total number of cattle ≥2 years in herd)
■ IBR in 1981

Table 2 - Prevalence of BHV1 reactors in suckler herds

Herd	Month/Year of test	Cattle aged ≥2 years		
		No	+	%
S1	7/87	24	2	8.3
S2	2/88	10	0	0
S3	2/88	18	1	5.5
S4	2/88	90	3	3.3
S5	3/88	56	6	10.7
S6	4/88	7	1	14.3
S7	11/88	16	1	6.3
S8	12/88	60	4	6.7
S9	1/89	20	0	0
S10	2/89	29	4	13.8
S11	5/89	25	0	0
S12	6/89	56	11	19.6
S13	7/89	25	2	8.3
S14	7/89	4	0	0
S15	7/89	5	0	0
S16	11/89	9	0	0
S17	12/89	27	6	22.2
S18	1/90	86	4	4.7
S19	2/90	76	42	55.3
S20	4/90	125	55	44.0
S21	5/90	18	0	0
S22	6/90	6	0	0
S23	9/90	10	3	30.0
S24	10/90	25	0	0
S25	11/90	12	0	0
S26	11/90	8	2	25.0
S27	11/90	16	10	62.5
S28	12/90	40	0	0
S29	12/90	13	5	38.5
S30	12/90	10	2	20.0
S31	12/90	22	2	9.1
S32	1/91	35	4	11.4
S33	1/91	35	1	2.9
Totals	7/87-1/91	1018	171	16.8

No Number of cattle tested for BHV1 antibodies
\+ Number of reactors
% Percentage of reactors

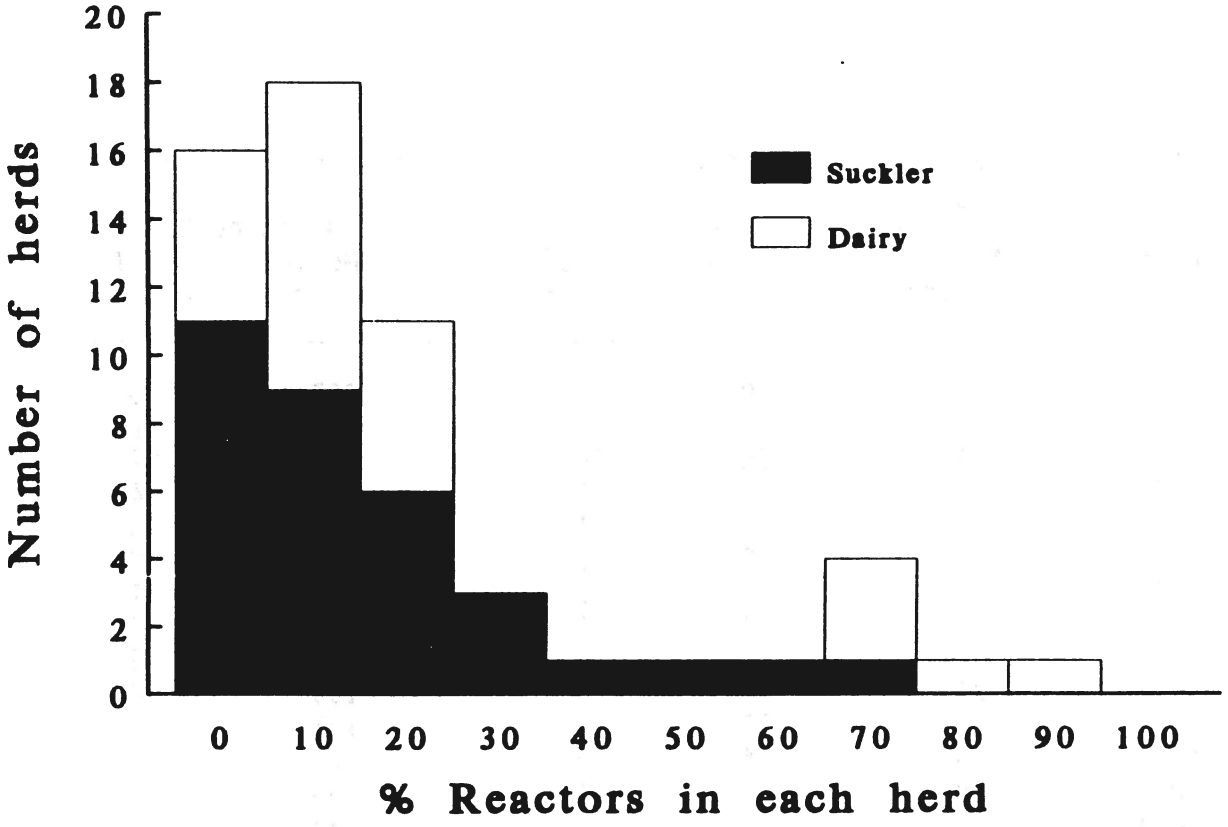

Fig. 1 - Frequency distribution of BHV1 reactors in CHS herds

Antibody prevalence according to source of origin

Breeding replacements were purchased from a wide geographical area, mainly outside Norfolk, extending from Scotland to the West Country and continental Europe. Only three herds (D1,D6,D9) had been completely closed during the previous 10 years (Tables 3, 4), with the mean number of purchases being 17.1 ± SD 17.5 in dairy herds and 22.7 ± SD 22.5 in suckler herds. The mean number of purchased cattle in dairy herds at the time of the test (7.2 ± SD 8.4) was less than half that in suckler herds (15.9 ± SD 20.1) but the latter included several recently established herds (notably S27, which had been formed a year previously from cattle purchased exclusively from S19). Significant correlations were noted in suckler herds, but not in dairy herds, between the number of reactors and the number of cattle purchased in the previous 10 years ($r = 0.42$ $p<.05$) and between the number of reactors and the number of purchased cattle in the herd at the time of the test ($r = 0.63$, $p<.01$). In dairy herds, the mean percentage of purchased reactors (41.3 ± SE 3.2) was significantly greater than that of homebred reactors (17.6 ± SE 0.7) ($p<.001$). In suckler herds this difference was less marked (13.9 ± SE 1.5, 9.9 ± SE 1.4 respectively) but still statistically significant ($p<.05$).

In two dairy herds (D8, D11) and 14 suckler herds (S1, S3, S6, S7, S8, S10, S13, S17, S26, S27, S29, S30, S31, S32) all reactors had been purchased; some comprised the original foundation stock, still in the herd after seven (S30) or eight (S6) years. Many of the purchased reactors in suckler herds, but not in dairy herds, were embryo transfer recipients known to have been vaccinated before introduction.

Table 3 - Prevalence of BHV1 reactors in dairy herds according to source

Herd	Purchased Cattle			Homebred Cattle	
	No in 10 years	No in herd	No of Reactors	No in Herd	No of Reactors
D1	0	0	0	227	0
*D2	25	5	3	55	2
D3	24	16	15	120	82
*D4	30	2	1	24	4
D5	2	2	1	252	13
D6	0	0	0	189	0
D7	60	34	7	99	11
D8	58	20	6	134	0
D9	0	0	0	123	6
D10	21	14	0	100	0
D11	10	10	1	107	0
*D12	6	4	0	26	0
D13	8	8	4	109	8
D14	8	8	1	132	1
D15	40	16	5	160	2
*D16	32	9	9	19	16
D17	2	1	1	259	18
D18	10	2	1	119	6
D19	10	0	0	52	0
D20	3	1	0	133	84
D21	25	4	4	143	88
D22	10	9	5	187	34
D23	9	0	0	267	29
Totals	393	165	64	3036	404

* Statistical screening only

No in 10 years: Total number of cattle purchased in the previous 10 years

No in herd : Total number of purchased cattle in the herd and included in the test

Table 4 - Prevalence of BHV1 reactors in suckler herds according to source

Herd	Purchased Cattle			Homebred Cattle	
	No in 10 years	No in herd	No of Reactors	No in Herd	No of Reactors
S1	20	12	2	12	0
S2	3	1	0	9	0
S3	18	3	1	15	0
S4	8	3	2	87	1
S5	30	23	4	33	2
S6	5	5	1	2	0
S7	36	6	1	10	0
S8	25	18	4	42	0
S9	6	6	0	14	0
S10	27	27	4	2	0
S11	8	4	0	21	0
S12	54	54	10	2	1
S13	25	25	2	0	0
S14	4	4	0	0	0
S15	3	3	0	2	0
S16	4	4	0	5	0
S17	24	12	6	15	0
S18	94	86	4	0	0
S19	65	47	21	29	21
S20	45	68	26	57	29
S21	18	18	0	0	0
S22	12	6	0	0	0
S23	4	4	2	6	1
S24	6	1	0	24	0
S25	4	3	0	9	0
S26	8	8	2	0	0
S27	16	16	10	0	0
S28	30	9	0	31	0
S29	13	13	5	0	0
S30	4	4	2	6	0
S31	70	4	2	18	0
S32	10	8	4	27	0
S33	50	20	0	15	1
Totals	749	525	115	493	56

No in 10 years: Total number of cattle purchased in the previous 10 years

No in herd : Total number of purchased cattle in the herd and included in the test

Antibody prevalence according to age

As shown in Tables 5 and 6 the mean antibody prevalence in dairy and suckler herds calculated from pooled data declined from about 6% in calves aged up to six months to virtually nil (only one reactor from 220 calves) by 12 months. Seroprevalence amongst yearlings, two-year-olds and three-year-olds was markedly lower in dairy herds than in suckler herds but since most of the latter reactors were limited to a few herds (particularly S19), statistical comparisons between herd types were considered inappropriate. From four years of age, mean seroprevalence increased at a similar rate in both types of herd and by 10 years, 45% of all cattle were reactors, including the eight (in herds D21,D22,S17,S30 and S32) that were 15 years or older.

All reactors detected amongst calves up to six months old and the single reactor aged nine months in D5 had received colostrum from known seropositive dams, with the exception of the reactor in S9 which had been purchased from a local market at two months of age. Single reactors were present amongst cattle less than two years old in three herds (D10, S9, S11) in which all older cattle were seronegative. Those in S9 and S11 were both purchases and that in D10 was a homebred heifer known to have broken in with a group of cattle of unknown disease status whilst grazing communal marshland about a month before the test.

As illustrated by the pooled data presented in Figs 2 and 3 the age-specific prevalence for individual herds revealed two distinct patterns of seroconversion which corresponded to the main antibody prevalence groupings noted earlier. In the four dairy herds (D3, D16, D20, D21) with a high prevalence (HP) of BHV1 antibodies (>60%) seroconversion appeared to commence amongst heifers within two or three months after they joined the main herd for calving; uncalved heifers on separate grazing were all seronegative. By four years of age, 75% of cattle in these herds were reactors. In the 14 dairy herds with a low prevalence (LP) of BHV1 antibodies (<20%) there was no such evidence of active infection amongst heifers after calving and less than 5% of cows in their second or third parity were seropositive. The proportion of reactors in LP dairy herds rose sharply after six years of age (Fig. 2); seroprevalence amongst cattle aged nine years or more was higher than average in D5, D7, D22 and D23 (Table 5).

Only three suckler herds (S19, S20, S27) showed marked increases in seroprevalence with age indicative of extensive virus circulation: these were also herds identified previously as having a high prevalence of BHV1 antibodies (>40%). Instead of commencing amongst recently calved heifers, seroconversion in the HP suckler herds appeared to start at between one and two years of age and to continue at a lower rate after calving than in HP dairy herds. The age-specific prevalence pattern in LP suckler herds (Fig. 3) was virtually identical to that recorded in LP dairy herds (Fig. 2).

Table 5 - Age-specific prevalence of BHV1 antibodies in dairy herds

Herd Ref	Age in years: 0 - ½		>½ - <1		1		2		3		4		5		6		7		8		9		≥10	
	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+
D1	4	0	32	0	30	0	70	0	38	0	34	0	27	0	13	0	15	0	10	0	8	0	12	0
#D2*									17	0	5	0	12	0	6	2	6	0	8	1	6	2		
■D3					70	1	4	0	23	5	23	10	32	31	23	22	9	9	6	6	3	3	13	11
#D4*							6	0	5	1	1	0	3	0	2	1	4	2	1	0	3	0	1	1
#D5			1	1	1	0	71	0	42	0	40	0	40	1	27	0	16	1	5	1	8	8	5	3
D6	19	0	28	0	68	0	13	0	48	0	32	0	30	0	28	0	16	0	9	0	3	0	10	0
#D7							24	0	17	0	21	1	27	2	21	0	4	0	2	1	8	7	9	7
#D8					25	0	30	0	20	0	14	0	22	0	32	1	28	5	6	0			2	0
#D9	7	0			46	0	17	0	20	0	18	1	15	0	16	0	9	0	13	4	4	0	11	1
D10	23	0	6	0	13	1	18	0	17	0	26	0	7	0	8	0	10	0	8	0	6	0	14	0
#D11	12	0	9	0	32	0	21	0	32	0	22	1	6	0	9	0	6	0	2	0	9	0	10	0
D12*									10	0	3	0	5	0	1	0	4	0	2	0	3	0	2	0
#D13	21	2			13	0	19	0	24	2	19	0	19	1	15	0	11	3	3	0	1	0	6	6
#D14	6	0			8	0	21	0	26	0	21	0	16	0	16	0	11	0	13	0	7	1	9	1
#D15							24	0	17	0	21	0	37	2	21	0	27	3	18	1	8	1	3	0
■D16*					2	0	2	0	13	13	3	3	2	2	1	1	3	2	1	1	1	1	2	2
#D17							54	0	24	0	39	0	41	0	37	1	12	0	21	3	12	2	20	13
#D18							7	0	28	0	24	0	22	0	14	0	7	1	2	0	10	2	7	4
D19	17	0	6	0	9	0	10	0	5	0	10	0	6	0	5	0	11	0	2	0	2	0	1	0
■D20					6	0	12	0	21	2	19	12	22	16	26	21	18	17	7	7	3	3	6	6
■D21							9	0	29	2	39	38	17	13	17	10	4	4	6	5	7	4	19	16
#D22					4	0	55	0	23	0	23	1	19	3	26	4	22	13	14	6	4	4	8	8
#D23	65	9	41	0	56	0	64	0	53	0	40	1	30	4	26	3	28	5	12	7	9	5	5	4
Totals	174	11	123	1	383	2	551	0	555	25	499	68	457	75	390	66	281	65	171	43	125	43	175	83
Reactors %	6.3		0.8		0.5		0		4.5		13.6		16.4		16.9		23.1		25.1		34.4		47.4	

* Statistical screening only ■ High prevalence herd # Low prevalence herd

Table 6a - Age-specific prevalence of BHV1 antibodies in suckler herds

Herd Ref	Age in years																							
	0 - ½		>½ - <1		1		2		3		4		5		6		7		8		9		≥10	
	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+
#S1	23	2	4	0	16	0	3	0	3	0	4	0	4	0	5	0			1	1	2	0	2	1
S2					15	0	5	0	1	0	3	0			1	0								
#S3									3	0	5	1	2	0	1	0	3	0	1	0			3	0
#S4	42	0	10	0	34	0	29	0	18	0	13	0	5	1	9	0	4	0	3	0	4	0	5	2
#S5			4	0	18	7	11	3	13	1	6	0	10	1	4	0	6	1	4	0			2	0
#S6	2	1			2	0	3	0	1	0	1	0					1	0					1	1
#S7	3	0	12	0			4	0	2	0	3	0	1	0	2	1	3	0	1	0				
#S8	2	0	14	0	22	0	22	0	10	0	9	0	6	0	8	0	1	0			1	1	3	3
S9	5	1			15	0	3	0	3	0	3	0	4	0	1	0	1	0	2	0	1	0	2	0
#S10					9	2	25	3	3	1													1	0
S11	2	0	13	0	3	1	4	0	4	0	4	0	3	0	3	0	2	0	2	0	1	0	2	0
#S12	11	1	9	0	23	0	11	0	10	1	5	2	6	1	3	1	2	0	2	1	2	0	15	5
#S13	21	2	3	0					19	0	4	1	1	0									1	1
S14	3	0							3	0			1	0										
S15					1	0	2	0							3	0								
S16	2	0	7	0	1	0	2	0	2	0	1	0	1	0			1	0	1	0	1	0		
#S17	6	0	12	0	7	0	4	0	6	0	3	1	4	0	1	0	2	1	1	1	1	1	5	2
#S18							23	0	2	1	31	0	30	3										

...continued/

Table 6b - Age-specific prevalence of BHV1 antibodies in suckler herds cont'd

Herd Ref	Age in years																					
	0 - ½		>½ - <1		1		2		3		4		5		6		7		8		9		≥10	
	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+	No	+
■S19					1	0	10	9	16	12	10	3	6	1	9	2	6	5	6	2	6	2	7	6
■S20					29	18	32	3	23	6	16	10	5	2	13	4	20	17	3	3	4	3	9	7
S21							18	0																
S22			6	0											6	0								
#S23							2	0	1	0			1	0	1	1					2	1	3	1
S24							7	0	8	0	1	0	4	0	1	0	2	0			1	0	1	0
S25			4	0			2	0	4	0			4	0			1	0					1	0
#S26	5	0			5	0	2	0					6	2										
■S27	5	1	4	0	4	2	6	4	4	3	2	0	2	2					1	0			1	1
S28							4	0	16	0	11	0	3	0	1	0	2	0			1	0	2	0
#S29							6	4	1	0	2	0	2	1	2	0								
#S30			1	0			3	0			1	0	1	0	1	0			2	0			2	2
#S31							13	0	9	2														
#S32					7	0	8	0	7	0	5	0	1	0	3	0	1	0	1	0	2	0	7	4
#S33							2	0	5	0	5	0	6	0	3	0	6	1			3	0	5	0
Totals	132	8	97	0	212	30	266	26	197	27	140	18	119	14	81	9	64	25	31	8	32	8	80	36
Reactors %	6.1		0		14.2		9.8		13.7		12.2		11.8		11.1		39.1		25.8		25.0		45.0	

■ High prevalence herd

Low prevalence herd

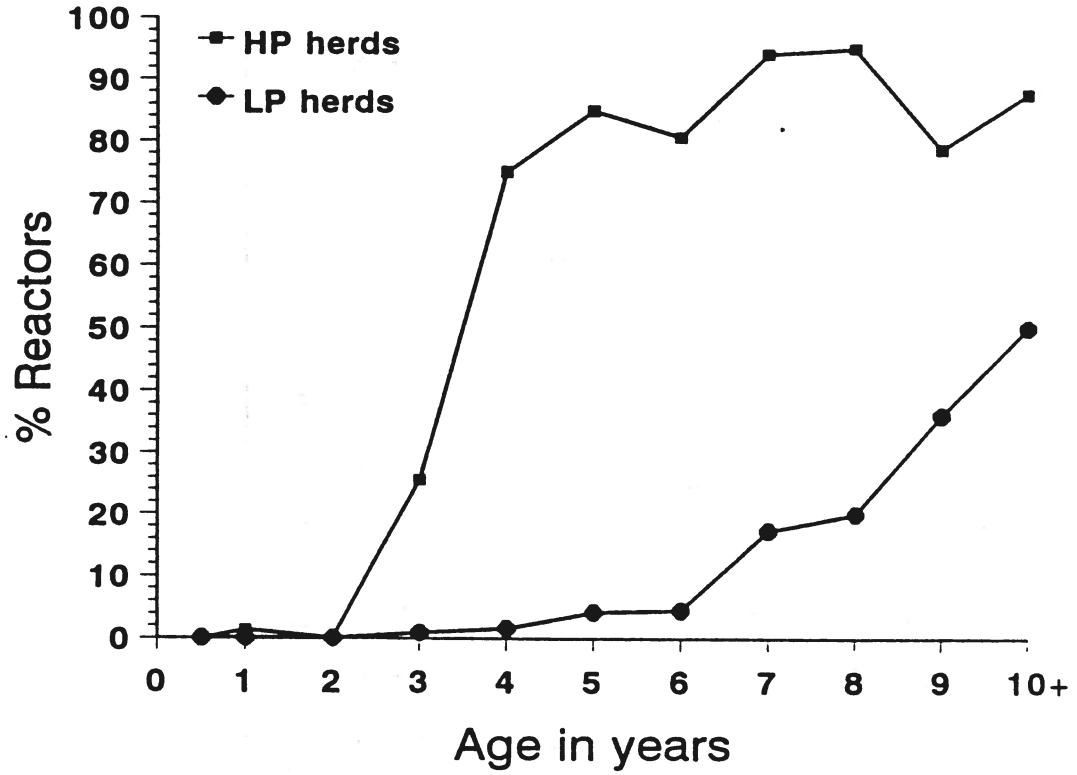

Fig. 5.2 - Seroconversion patterns in dairy herds according to antibody prevalence category

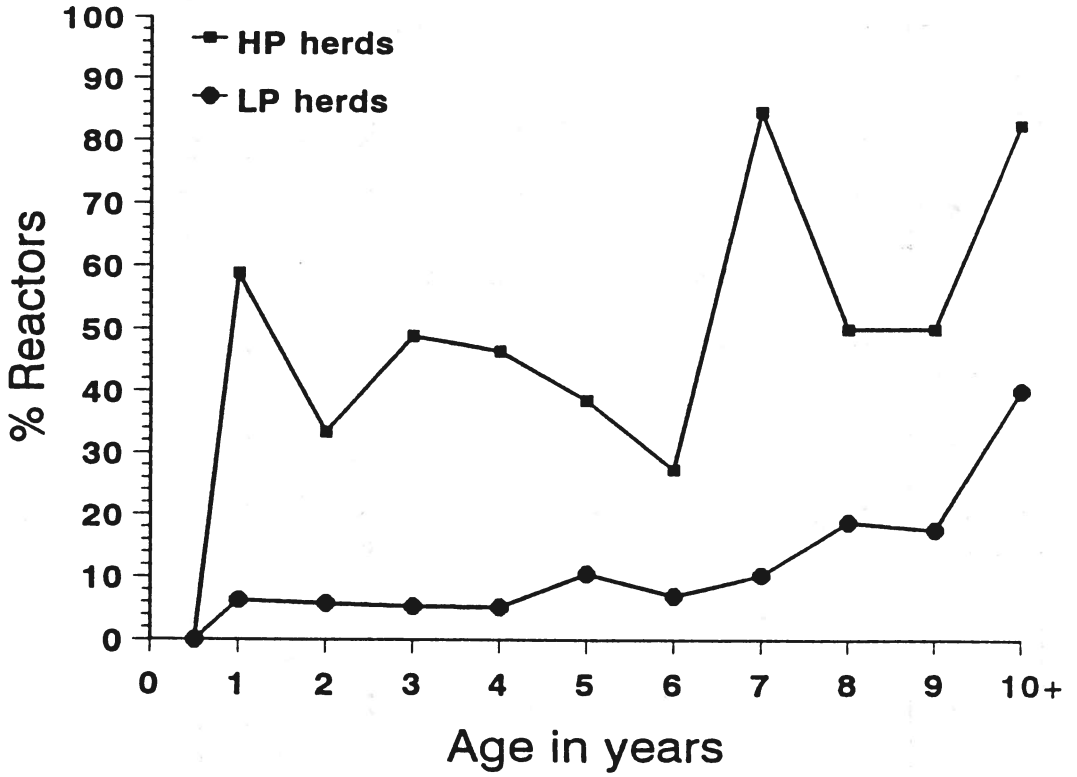

Fig. 5.3 - Seroconversion patterns in suckler herds according to antibody prevalence category

DISCUSSION

The 56 herds included in this study represented about 9% of all dairy and suckler herds containing 10 or more cows listed in the 1989 agricultural census for Norfolk (MAFF, 1990). The extent of BHV1 infection in this sample population was essentially unknown before investigations commenced: apart from D13 which had experienced an epidemic outbreak eight years previously, none of the herds had any clinical history of IBR. The large proportion of herds with a low prevalence of BHV1 antibodies appeared similar to the situation in Germany (Forschner, 1988) and Spain (Espuna et al, 1988). The latter authors lent further support to the present studies by also finding that herds tended to be either heavily or lightly infected, with few having intermediate seroprevalence.

The significant correlation between herd size and the number of reactors in suckler herds appeared mainly to reflect a tendency for larger suckler herds to contain more purchased cattle. On average, suckler herds contained more than twice as many purchased cattle as dairy herds. The four largest dairy herds (D1, D5, D17, D23) had purchased a total of only 13 replacements during the previous 10 years. The strong association between reactor status and purchase supported the generally accepted view (Gibbs & Rweyemamu, 1977; Pastoret et al, 1984) that BHV1 is most frequently introduced by the addition of latently infected carriers to susceptible herds.

Remarkably, purchased cattle - including many that had been in the herd for several years - were the only reactors detected in 16 of the 40 infected herds, suggesting that no virus transmission had occurred following their introduction. Similarly, in herds in which some homebred cattle were also reactors, anecdotal information often suggested sources of infection other than lateral spread from purchased animals. In S4, for example, the only homebred reactor was a bull that had been loaned to a herd in the south of England for four months before returning to Norfolk; in D13, six of the eight homebred reactors had been in the herd during the IBR outbreak recorded in 1981. No satisfactory explanation was found for the exclusively homebred reactors in D9 and S33 but it was assumed that they had acquired infection in unrecorded incidents, similar to that in D10, in which a heifer broke in with a group of other cattle.

Two of the homebred reactors in D18 were specifically identified as having attended several agricultural shows. However, several other large herds had exhibited cattle at six or seven major shows each year for the previous 15 years without any evidence of them acquiring infection from this source. Although detailed records were rarely available to make any systematic risk assessment, the present findings suggested that agricultural shows and similar livestock events did not pose any major threat, particularly when there was only a short period of close contact with other cattle.

Overall, field observations suggested that, in most herds, the risk of virus being transmitted from seropositive cattle (including vaccinates) to susceptible in-contacts was quite small. Although reexcretion of latent virus is undoubtedly of potential epidemiological importance, its role under natural conditions, in the absence of experimental provocation, appears to have been overestimated. Van Nieuwstadt & Verhoeff (1983) similarly found no evidence of virus transmission for at least three years in eight of 20 dairy herds in Holland and Baker et al (1989) detected only a very low rate of transmission of live intranasally administered vaccinal virus to co-mingled steers. In contrast, widespread virus circulation, manifested by a high rate of seroconversion, was clearly evident in the seven herds with the highest antibody prevalence. Presumably, these herds were initially infected via purchased replacements or similar sources but unlike in LP herds, the virus then appeared to have spread rapidly to susceptible cattle, amongst which it was maintained sufficiently to infect each year's input of heifers.

There were no discernible differences between HP and LP herds in environmental or intercurrent disease stress factors likely to cause viral reactivation. Edwards et al (1991) found that calves infected with BHV1 subtype 1 excreted more virus than those infected with subtype 2b strains and it appeared likely (S Edwards, personal communcation) that the apparent difference in virus behaviour between LP and HP herds was associated with different strains of virus, possibly beyond the sensitivity of simple restriction endonuclease fingerprinting techniques. This hypothesis was supported by the observation that herd S27, which was formed entirely from cattle in S19, had assumed the seroconversion pattern of its parent herd.

Corkish (1988) suggested that calves in suckler herds were more likely to acquire infection from their dams than those in dairy herds which were removed soon after birth. There was, however, no serological evidence from these studies to indicate that active infection had occurred amongst calves aged less than a year. Maternally derived antibodies invariably disappeared by about six months and although sera were examined from calves in only one (S27) of the three HP suckler herds, consistently seronegative findings from calves in other herds in this age range suggested that the likelihood of them acquiring infection through sucking seropositive dams was small.

Seroconversion occurred amongst 12 - 24 month old heifers in HP herds S20 and S27 but not in the HP dairy herds. This difference was attributed to the management practice commonly adopted in suckler herds, whereby maiden heifers were housed close to adult cattle during the winter. Similar findings, including seroconversion amongst yearlings, were noted in suckler herds in the north-west of Scotland (N. G. Brookes, personal communication). In dairy herds, replacement heifers were almost invariably maintained as completely separate populations, on marsh or upland grazing, until they joined the milking herd after calving. Hence, provided they did not acquire infection from outside sources, uncalved heifers from HP dairy herds were seronegative on

entering the milking herd. By comparing serological status with date of calving it appeared that most subsequent seroconversion in HP herds occurred two or three months after calving, coinciding with winter housing.

In LP herds the likelihood of cattle becoming reactors did not increase until after six years whereas most cattle in HP herds had seroconverted by this time. Regardless of prevalence category almost 50% of all cattle in infected herds, aged 10 years or more, were seropositive. The preponderance of reactors amongst older animals suggested that even the LP herds had been heavily infected in the past, but with regular routine culling, infection was gradually working its way out of these herds. Provided it is not reintroduced, self-elimination of BHV1 from LP herds appears to be inevitable in view of the lack of spread to susceptible herd members. Van Nieuwstadt & Verhoeff (1983) similarly suggested that BHV1 might disappear in the long-term from herds in which no recent virus circulation had occurred. Conversely, BHV1 infection was likely to be maintained indefinitely in HP herds unless there was a change in virus behaviour or in some environmental factor not apparent from these studies. There was no obvious explanation to account for the presence of eight seronegative cows from amongst the 57 aged 10 years or more in the seven HP herds.

Because of the high rate of virus circulation detected in HP herds, further enquiries were made to check whether there was any clinical history that could possibly be attributed to BHV1 infection. These revealed that in August 1989, four recently calved cows in D21 experienced pyrexia and milk drop; a further similar case occurred in October 1990. No BHV1, bovine virus diarrhoea virus or Leptospira hardjo antibodies had been detected in blood samples taken from these cows at the acute stage of illness but when they were retested for the CHS in February 1991 all five were found to have seroconverted to BHV1. Although not conclusive because of the long time interval between testing, this evidence suggested that the herd had experienced clinical recrudescence. Further evidence linking recrudescence and HP status, in the absence of a history of epidemic IBR, subsequently emerged from D3. At the time of the herd test in 1987 there was no clinical history of BHV1 infection but several recrudescences were subsequently confirmed by paired serology amongst second and third parity cows between 1989 and 1991.

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REGIONAL ERADICATION OF SWINE DYSENTERY BY GRADUAL ELIMINATION OF THE PATHOGEN FROM INFECTED HERDS

TH. BLAHA*

Like in other countries, there where different phases of the swine dysentery control according to the knowledge on the aetiology and pathogenesis of the disease. In the sixties, when the first outbreaks of swine dysentery occurred, no purposeful measures could be carried out and the disease spread rather rapidly. Since the communicability of the disease was suspected, often the depopulation- repopulation of pig units was ordered by the local Veterinary Officers. The spread of the disease throughout the country, however, could not be prevented by this method.

After the availability of dysentery-efficient drugs (first arsenicals, then tylosin) the depopulation-method was replaced by treating diseased animals. In this phase, the treatment was not based on an exact diagnosis, and, as a consequence, often the treatment failed. Only after the discovery and description of the agent by Tom Alexander and Hank Harris (Treponema (T.) hyodysenteriae, recently renamed to Serpulina (S.) hyodysenteriae) correct differential diagnostics could be carried out and the treatments became more effective. The drugs which were used were mainly metronidazole and tylosin. However, despite the improved treatment, in most cases the disease lingered on in herds once infected, i.e. clinical signs recurred in the herd again and again after treatments. This led to the necessity of the constant use of drugs in affected herds, which is very costly, especially in a country in which the drugs needed had to be imported with "hard" currency. Therefore, it was looked for methods to stop the frequent recurrence of the disease in the herd.

This search for a method that made better use of the expensive and rare drugs resulted in a control measure which was called "treatment for sanitation". In order to prevent the reinfection of treated animals by latently infected animals in the herd, the whole herd (except of piglets younger than two weeks of age) was treated either orally with 25 mg metronidazole/ kg body weight or parenterally with 10 mg tylosin/ kg body weight on 7 consecutive days and after an interval of 3 to 4 weeks again on 5 consecutive days. Simultaneously , always after the treatment of all pigs, the direct environment of the pigs (pens, floors, walls) were cleaned and disinfected with the pigs remaining in the sties. Mainly peracetic acid was used. The result of this kind of treatment was a considerable improvement of the herd health at all in treated herds and often the herds remained free from swine dysentery for

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longer periods. In the meanwhile, in 1977, swine dysentery was declared a notfiable disease in order to have a better control of the use of the drugs. However, it is true that some herds treated in the described way remained dysentery-free until now, but in most herds swine dysentery recurred after a shorter or longer period despite of the correct carrying out of all measures. The only explanation was: reinfection of the herd by so far unknown sources. The result was that the nation-wide incidence rate of swine dysentery could not be reduced.

In the late seventies and early eighties the research on the epidemiology of swine dysentery was intensified. By this the role of latently infected pigs, especially of latently infected herds in which clinical signs haver never been seen, and the role of rodents for the spread of the agent was defined. Now, a regional eradication by not only the "treatment for sanitation" of diseased herds, but also of all latently infected herds and by controlling the rodent populations of herds (clinically diseased and latently infected) could be recommend to the State Veterinary Service. In order to prove the feasibility and the success of so costly a control method, a regional eradication trial was carried out in a selected county of the Bundesland Thuringia with about 600 000 pigs. The "treatment for sanitation" was to be carried out only in breeding herds, since the basic idea was that, if only "treponema-free" piglets are delivered to fattening units, the disease will die away in fatteners as well.

The first step was the identification of the latently infected breeding herds, performed in 1981. All 65 breeding herds of the region were investigated as follows: 100 faeces samples were checked for the presence of treponemas by phasecontrast microscopy. Any live treponema found, even if only one in one sample, led to the classification: "treponema-positive". Only if in 3 times 100 samples (intervals of one week) out of one herd, no live treponema was found, the herd was classified "treponema-free". In the following three years, the following measures were carried out on all herds in which clinical dysentery occurred or which were classified "treponema-positive":

1. Preparing the farm

   - tidying up and cleaning
   - removal of dung and slurry
   - lowering the stocking density
   - radical rodent control and avoiding new rodent immigration by using so-called attracting boxes

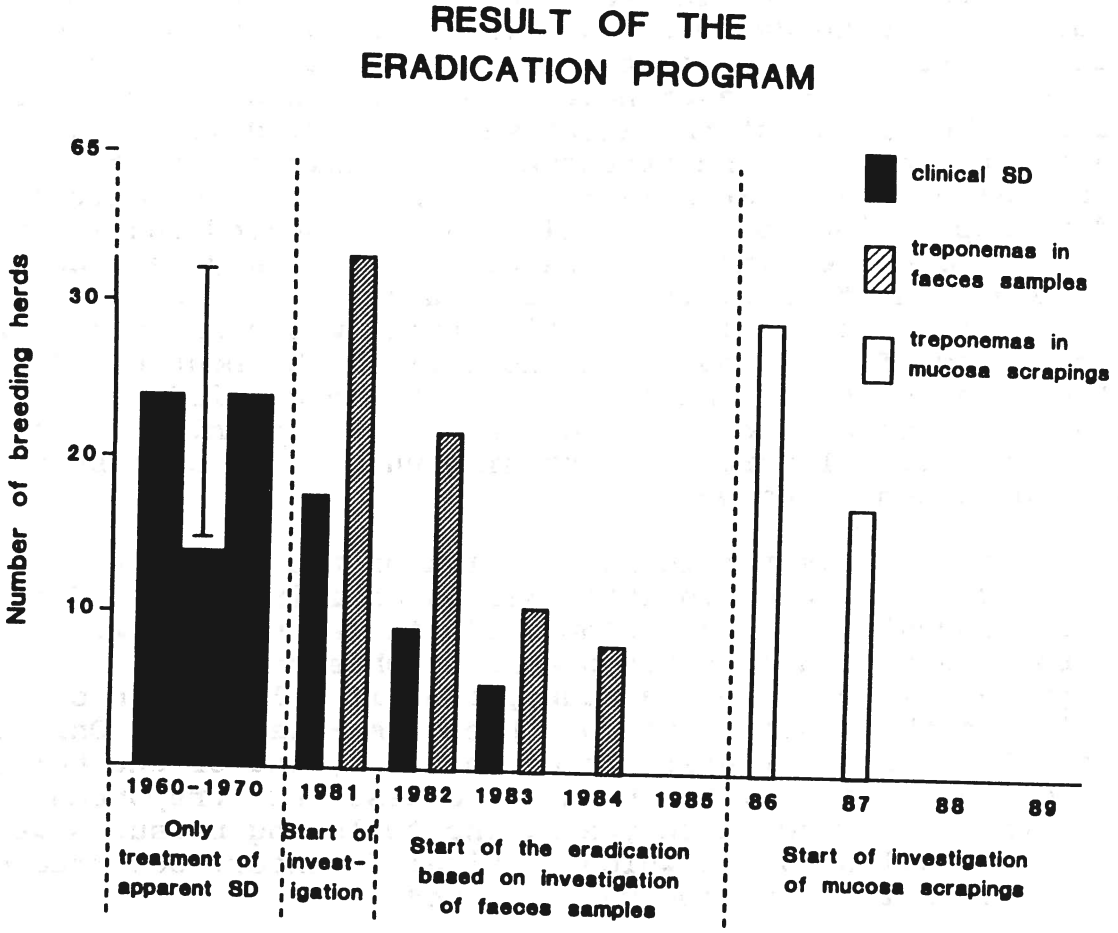
2. Herd sanitation

   - medication of all pigs in the herd on 7 and 5 consecutive days at an interval of 3 to 4 weeks
   - cleaning and disinfection of all pens after each medication
   - 3 times 100 faeces samples at one-week intervals for controlling the result (beginning after the treatment)

3. Maintenance of pathogen-freedom

- introduction of only animals from "treponema-free" herds or
- quarantine with investigation and (if "treponema-positive") treatment of the whole animal group
- maintaining the high hygiene status
- continuation of rodent control and avoidance
- monitoring of the pathogen-freedom (preferably by the investigation of colon mucosa scrapings)

Figure 1 shows the result of the eradication programme.



As demonstrated in Fig. 1, no clinical dysentery occurred in the region from 1984 onwards. In 1985, even no treponemas were found in altogether 24000 faeces samples. Therefore, the investigation of faeces samples was stopped and replaced by the investigation of scrapings of the colon mucosa of all pigs from the breeding herds sent for post-mortem investigations to the Regional Investigation Centre (there was the duty of regular post-mortem investigations of certain percentages of pigs died in the breeding herds). In 1986 and 1987, some treponemas were found in the mucosa scrapings, the number, however, decreased towards zero in 1988. The explanation for this can only be that no infection chains could come into being since the shedding of the pathogen was not

"sufficient" enough. From 1984 to 1990, no "dysentery-drugs" were used both in breeding and in fattening units of the region.

Evaluating the result, the trial has proven:

1. The eradication of swine dysentery is not only possible from herds, but also from regions.
2. Although there is no evidence for the total disappearance of S.(T.) hyodysenteriae, below a certain number of pathogens shed from only few animals the infection chains get interrupted.
3. The high costs of the eradication procedure are repaid for at last after 6 months pathogen-freedom by the considerable decrease of the amount of antibiotics needed and the higher performance of the herd. The benefit of the eradication exceeds the costs the more, the longer the dysentery-freedom can be maintained without using dysentery specific drugs.
4. The eradication led to a remarkable reduction of the amount of antibiotics administered to the herd during the pigs' life, which is more and more important to guarantee the consumers' acceptance of pork.

It is quite obvious that the eradication procedure described cannot easily be transferred into the free-market economy, since the measures cannot be ordered as in the centralized economy of the former GDR. Therefore, at first sight the trial seems to be of no use for the pig industry in countries with a free market economy. Considering the benefits of a long-lasting freedom from S.(T.) hyodysenteriae, however, the eradication procedure, carried out on a voluntary basis, could be of great use for companies which include pig breeding, fattening and slaughtering, for hybrid-breeding companies, for breeder-fattener-organizations and for "quality-pork-programmes". Any organization needs, of course, its special design of the eradication programme, the basic principles of the eradication, however, should be like those described in this paper.

RAPID APPRAISAL TECHNIQUES: A TOOL FOR PLANNING AND MANAGING ANIMAL HEALTH AND PRODUCTION DEVELOPMENT PROGRAMMES

M. GHIROTTI*

"The method employed helps to determine what kind of facts will be gathered; the facts, in turn, lead to the development of theories; and the theories, in their turn, influence methods"

Edgerton and Langness (1977)

In the last decade there has been increasing concern among researchers and development workers of different disciplines about the need to develop and utilize field diagnostic techniques which, trying to combine rapidity with sound scientific methodology, allow a systematic identification of constraints (or working hypotheses for investigations), the testing of possible solutions to overcome them and the monitoring of activities. Such concern has been quite evident in developing countries where resources to invest in these activities are scarce. Moreover, decision-making by many international agencies has often been exposed to the spatial, social and seasonal bias of "development tourism" (visiting, during quick trips, project areas near main roads, contacting local elites and other representatives of privileged segments of the society in healthier periods of the year); to the lack of a common framework for the collection of data; and to a sectoral approach of most academic researchers (Carruthers and Chambers, 1981). A major contribution has come from social sciences and from the "participants observation" approach. Such a research method involves the direct study of a community and, in so far as possible, participation in its life and activities (Edgerton and Langness, 1977).

INFORMATION AND DEVELOPMENT

Animal health and production interventions such as disease control, livestock upgrading and marketing, veterinary public health programmes are part of the process to develop a given area and community. Availability of appropriate data is crucial for the planning, management and evaluation of such activities so that resources can be best invested and intended results achieved. Epidemiology has provided powerful tools for the purpose (Abramson, 1984; Putt et al., 1987).

Well-designed baseline surveys are sometimes carried out before implementing large-scale activities. They are critical to assess accurate disease frequencies or productive levels in herds, so that proper objectives can be selected and results monitored during project implementation (ILCA 1983; FAO, 1984). However, too often the collection, consolidation, elaboration and feedback of such data is considerably lengthy. Moreover, in many developing countries background information is scarce, communication

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networks poor and resources very limited. Recommendations and hence development projects or research proposals, designed on the basis of these results, may be drawn when the situation has already changed and the selected objectives are no longer valid.

Large surveys imply high running and opportunity costs for the veterinary and other services involved because of the difficulties to ensure correct sampling using standard procedures. To ensure high accuracy, relatively large numbers of samples are needed from a population often scattered in the territory and of which little is known about its distribution and stratification (Putt et al., 1987). Consequently, the studies are designed to collect as many samples or measurements in the shortest time possible in order to minimize costs. Even questionnaire surveys are seldom designed as opportunities to discuss potential project objectives and activities with the members of the target community who are often merely used as a tool for the collection of the required data. Such an approach does not allow the investigators to benefit from the huge experience acquired by local farmers and from the practical hierarchy of priorities and possible solutions they might have already developed and tested. At the end of the study, researchers and development workers may end up proposing solutions already adopted or rejected by the farmers or investigating phenomena which livestock owners know in detail. Moreover, community involvement not only in the implementation but also in the planning and evaluation of any developmental activity has been widely agreed as a critical factor for the success of any animal disease control and livestock production programme (ILCA, 1977; WHO, 1990).

Other reasons have encouraged researchers to develop techniques that are complementary to standard surveys. For example, correct planning recommends that the analysis of the problem (i.e., the epidemiology of a given disease or other constraints in herd productivity) must be performed together with the analysis of the overall situation (i.e., environmental, socio-economic and cultural features) through an holistic approach (Bainbridge and Sapirie, 1974). The health and productivity status of a livestock population should be analysed within its farming system(s) trying to understand the role played by the different components of the system (Jankhe, 1982). Moreover, veterinary care should be considered as part of the whole health system (Schwabe, 1978; WHO, 1990). Disease prevalence or herd structure and productivity are dynamic processes whose outcome is the result of the interaction of different factors internal and external to the system. The nature and respective importance of such determinants may not be fully appreciated by an external investigator alone, especially when the causes are peculiar to the local situation. On the other hand, the key to interpret crude data may be provided by the farmers' experiences.

RAPID APPRAISAL

Rapid appraisal (RA) methodologies aim to benefit of farmers' experience and perspectives. RA has been defined as: "a systematic .... semi-structured activity carried out in the field by a multidisciplinary team and designed to acquire quickly new information on, and new hypotheses about.... development" (McCracken et al., 1988). These techniques present several

advantages since they:

- take into account local conditions,
- encourage an upside down approach,
- utilize interdisciplinary experiences,
- economize in time and other resources,
- try to reduce a complex situation to a few key questions,
- emphasize not only productivity but also stability, sustainability and equitability of a system,

RA has been developed and used mostly in rural situations and in the agricultural sector. This paper describes the different to be taken in order steps to perform a rapid appraisal aiming at having a quick, systematic and cost-effective picture of livestock conditions and veterinary problems especially in agropastoral communities. The original methodology was first set up in the Central Ethiopian Highlands in 1985 (Ghibe Valley) and further tested and improved in various areas of the Shoa region of Ethiopia, in the Kafue flats of Zambia, in the Quiche area of Guatemala, in Sidamo Awrajia of Southern Ethiopia and in the Owamboland of Namibia. A further paper will discuss the principles and techniques for the analysis of veterinary problems under urban conditions.

MATERIALS AND METHODS

The main steps in carrying out RA for livestock development are the following:

1) early identification of the problem(s) and RA objectives
2) constitution of the team
3) identification of target areas and communities (e.g., main eco-agricultural systems in the area under study)
4) desk research and interviews of professionals
5) information and discussion with the central and district authorities of the study objectives
6) preliminary visit to the communities

    6.1 presentation to local authorities,
    6.2 identification of major groups and informal leaders
    6.3 presentation of the study objectives
    6.4 semi-structured interviews of key informants
    6.5 drawing up of main environmental, livestock and community features

7) setting of final objectives
8) data collection

    8.1 identification and selection of clusters of herds or households
    8.2 questionnaire interviews of individual farmers
    8.3 measurement of selected indicators
    8.4 collection of specimens
    8.5 recording of selected case histories

9) data analysis and interpretation of results
10) feedback and discussion with the community
11) discussion of the results with central authorities and colleagues

12) dissemination of collected information
13) research or development project phase

and possibly:

14) follow-up

14.1 further contacts and interviews of key informants
14.2 periodical recording of the dynamics of selected herds
14.3 collection of selected samples and other data
14.4 feedback to community, authorities and colleagues.

1) Early identification of the problem(s) and RA objectives

As suggested by McCracken et. al. (1988) there are different classes of RA: exploratory, topical and monitoring RA. Veterinary and livestock officers or researchers may decide to perform RA to analyse and describe the general features and constraints of the livestock production system(s) present in the area where they are working (**exploratory RA**). Such a decision is recommended for the establishment or redefinition of development programmes and for the case organization of local livestock services according to farmers' needs. RA may also be performed to evaluate the progress or the impact of development activities or of veterinary services (**monitoring RA**). In both cases it is recommended to clarify which is the target group since livestock ownership and husbandry practices differ according to ethnic and social groups. For example, in many societies low income households seldom own large animals but rather small ruminants, pigs and fowls. Moreover, the productivity, functions and problems of livestock owned by underprivileged social or ethnic groups are different from those of other segments of the society. Examples are accessibility to drugs or to supplementary feeding and herd composition (Ghirotti, 1988). If such general information is already available, more specific objectives and areas of investigation could be selected (**topical RA**) according to the hierarchy of needs espressed by the community and to research objectives. Additionally, we suggest that researchers could carry out RA together with investigations on already identified topics to have a clear conceptual framework for a better interpretation of the results of more selective studies (**framework RA**). For example, the RA methodology was tested as a diagnostic tool to identify and describe local livestock production systems in the Ghibe area while investigating the importance of grazing dynamics in the reproductive behaviour of local zebu cattle and on the role of male animals in herd fertility (Ghirotti and Woudyalew, in press). In Southern Zambia, RA was utilized to identify husbandry practices, cultural and environmental factors which may help to interpret the results of a sero-epidemiological investigation on major cattle diseases and to identify valid and acceptable control measures (Ghirotti et al, 1991.)

2) Constitution of the team

The team should benefit as much as possible from the contribution that different disciplines can provide in the management of animal resources. However, it should consist of a maximum of four persons. A small team is probably more agile, discreet and likely to be accepted by the community

during field visits. Division of duties and the sharing of opinions is easier and faster among few members. Preferably, the team should be composed of:

- a veterinarian with a sound knowledge of animal production, epidemiology and disease economics;
- an ecologist (or an agronomist) with a good background in pasture management and animal population dynamics; and
- a social scientist who is acquainted with pastoral and agropastoral societies.

Each of them should have an intersectoral approach in problem analysis and solving. Naturally, the composition of the team can be modified according to the available human resources and to the nature of the specific topics to be investigated, once the presence of members who are competent in the above-mentioned disciplines has been assured. Local technical officers should be included in the team. As the team is formed, the leader should organize a workshop to discuss with the other members the study objectives and methodologies to be adopted, including criteria for the selection of the communities to be surveyed.

3) Identification of target areas and communities

The choice of target areas and communities mainly depends on:

- the study objectives,
- the type of selected RA, and
- the available resources.

The population involved in the analysis should be stratified on the basis of the selected variables to be investigated such as: main eco-agricultural systems to analyse (e.g., intensive vs. traditional livestock systems, different ecosystems), presence vs. absence of a given factor (e.g., crossbreeding schemes, vaccination, tick control and other veterinary services, credit facilities), different socio-cultural groups. The target community(ies) can be the one(s) involved in a given development programme which is implemented on an a priori defined area. In case we wish to analyse the general features of a given farming system or monitor a specific programme but we have limited resources such as time, funds and transport, the selection can be based on "representative" reachable villages. In some countries or regions permission to travel or to contact farmers may be restricted to some areas due to security reasons or because the communication network may be poor. However in such cases, the team should be aware of the potential sources of bias and of the difficulties in generalizing from the results of the analysis thus carried out. If the above-mentioned limiting factors are not present, sufficient resources are available and a reliable and representative picture of the situation is needed, few communities can be randomly selected (e.g., using a list of villages or a map). Stay in each village may take 2-3 days plus the time for travelling.

4) Desk research and interviews of professionals

Before performing a preliminary field visit, secondary information could be collected through published or unpublished documents: papers, reports, theses, newspapers, etc. Geographical and meteorological data as well as maps are the most elementary but fundamental data and material to be collected. Valuable practical advice can be obtained from experienced professionals who have previously worked in livestock development, disease control, "on farm" research and other community-based programmes.

5) Information and discussion with the central or local authorities about the study objectives

Administrative and technical authorities should be informed about the scope of the study and contribute with their comments to a better identification of the objectives. Dedicated officers can be an excellent source of reliable information on the livestock situation in the study area (including census data, existing legislation and impact of previous government policies). For example, where livestock ownership is taxed, farmers may be reluctant to give information on the composition of their herds; vaccination campaigns or dip tank records may provide rough estimates about animal populations, notably of large ruminants. The approval and clearence of national or regional offices is indispensable for the success of the activity and in order to benefit from the assistance of district and local authorities. Central authorities should be informed about the areas to be visited for the RA so that they may facilitate the field trips of the team. They should also be informed about the confidential nature of the data to be collected but at same time they should be assured that they will benefit from the RA results.

6) Preliminary visit to the communities

Correct information from farmers can be collected only if their trust is gained. The preliminary visit has the main purpose to present and discuss the study objectives with the community and local representatives and to obtain background information on the local farming and livestock system(s) before starting deeper investigations. It may happen that farmers are unwilling to collaborate, or that they are too busy at that time of the year, or that most of the heads of household or animals (i.e., contract herds in West Africa or transhumance) are away: interviews should be arranged when convenient for the farmers, e.g., around main festivities. Informal leaders, such as religious leaders, chiefs and headmen, representatives of social organizations should be contacted where feasible since their support is often indispensable to gain the farmers' trust and because in some areas government authorities may be disliked. Their social role should always be acknowledged and respected. Particularly in remote areas no reliable information can be obtained without their assistance.

During this preliminary the visit main environmental features, as well as social and ethnic groups could be identified and recorded and key informants interviewed. Key informants are persons who have specialized

knowledge that most of the community does not share (Edgerton and Langness, 1977). Examples of key informants are: different formal and informal leaders, representatives of farmers' and womens' associations, teachers, veterinary assistants, agricultural and health workers, successful and respected individual farmers as well as poor farmers, religious leaders, ethnic and clan leaders, elderly people. The main information to be systematically collected in such a way comprises:

a) local cropping calendars and agricultural practices: livestock production. Constraints and husbandry practices should be analysed within the farming system and related to other agricultural activities;
b) seasonal variations in labour demand (for men and women) and main festivities: meetings with farmers and eventual project activities involving their active contribution should be concentrated in the slackest periods of the year. Animals are slaughtered mostly for ritual purposes during festivities and their post-mortem inspection may provide information and specimens. Some operations on livestock are also ritually performed on such days: for example, in the central highlands of Ethiopia castration of bulls is carried out on Maskal, an important local festivity (Ghirotti and Woudyalew, in press);
c) main environmental changes and social events in the past years (e.g., historical events, introduction of new farming practices, disease outbreaks which have occurred in the area): they may have caused changes in production strategies, husbandry practices, livestock performance or disease occurrence. Such information will assist in the interpretation on data collected in the latter phases of the RA;
d) species and breeds of livestock kept and main husbandry practices, including spatial distribution and changes in species and breeds of livestock kept in the past. This may have not only brought differences in productivity and land utilization, but the presence/absence of species and breeds can be used as indicators (e.g., browsers rather than grazers as a sign of land degradation, degree of susceptibility to diseases such as trypanosomosis, tick-borne diseases, streptothricosis, foot-and-mouth disease);
e) purposes for keeping animals and their role in the farming system and household economics;
f) average productive parameters and their seasonal trend such as: fertility, milk or egg production, productive career, different types of offtake (rough percentage of sales, exchanges, gifts or slaughter);
g) estimation of number of herds and households present in the area;
h) vernacular names of most common diseases in livestock and in man, their importance and spatial/temporal distribution, local health beliefs and care systems;
i) main development constraints and public health problems and their spatial/temporal distribution;
j) development programmes and facilities (e.g., crushes, dip tanks, veterinary clinics, weighbridges) present in the area and arguments in favour and against existing or eventual development activities;
k) food of animal origin most commonly produced, consumed or sold, including existing food taboos, and use of other animal products or by-products (e.g., dung, rumen content, horns);
l) main sources and availability of feed (including use of by-products) and watering;
m) distribution, nature and composition of present wildlife populations: the presence or absence of different wild animal species in the area can be used as an indicator of the degree of pressure of human settlements and activities on the ecosystem. Wildlife is often a source of animal

products alternative or additional to the ones from livestock (e.g., bush meat);

n) presence and distribution of pests and vectors of diseases.

The presence of a commonly-used local calendar should be investigated so that the interviews can refer to such calendars: traditional calendars relate to seasonal changes and thus to the agricultural activities and farmers can remember past events better and thus give more precise answers. For example, in the Ethiopian highlands, local calendars begin in August-September which corresponds to the end of the rainy season when grains are about to be harvested. Seasonal prices for agricultural products could be collected at local markets (Ghirotti, 1988).

7) Setting of final objectives

From the results of the preliminary visit and the suggestions provided by the contacted community, the final objectives can be identified by the team. Questionnaires can now be designed and further background information on the subjects to be investigated can be collected. Preferably, some days should pass between the preliminary visit and the data collection at household level, especially if the team members are not already known to the community. However, under some practical circumstances, it is not possible to wait so long. In this latter situation, the community should be informed before the visit about the study objectives.

8) Data collection

Data can be obtained and checked through questionnaire interviews, direct observation of selected indicators, case histories and interviewing of groups of farmers or animal owners. Household visits and interviews can provide a large amount of valuable data using a questionnaire to standardize answers and asking explanations and opinions from the farmers. The questionnaire should concentrate on a few selected quantitative features which, integrated with the information already gathered through the semi-structured interviews, can give a good picture of the situation. The herd structure and its main parameters can synthesize the health and production status. For ruminants, data to be recorded from each herd/household are the number of:

1) calves, kids or lambs (animals below one year of age) born and died within the last 12 months;
2) adult females in reproductive age (conventionally, in traditional systems cattle above four years of age and sheep and goats above one year old);
3) adult females not in reproductive age (i.e., heifers between two and three years of age);
4) adult entire males (above one year of age);
5) adult castrated males (e.g., oxen);
6) adults which died within the last 12 months;
7) animals sold, slaughtered or given away within the last 12 months.

The same data apply to equine animals. From such data it is possible to

estimate herd fertility rates (i.e., calving, kidding, lambing percentages), mortality percentages below or above one year and offtake rates. In other words, the potential level of expansion or contraction of the herd. For further discussion on this topic, see Matthewman and Perry (1985) and Baptist (1990). The relative proportion of the different age/sex classes can provide additional information not only on herd growth, but also on the main purposes for keeping livestock. Possibly, monthly distribution of births and deaths should be obtained as well as the main causes of losses.

For fowls, information should be collected on the number of adults and chicks owned, number of chicks which were born and which died during the year and number of adults sold, slaughtered or given away. Bee-keeping and breeding of domestic rodents are often other important sources of food and income to be investigated. In some disease control programmes, e.g., rabies, the ownership of pet animals may be investigated.

For sampling purposes, two different types of clusters can be chosen for livestock data collection:

a) the household or
b) the grazing unit.

In the former case, the investigation pattern is to identify the household whose herd might be studied. In the latter the pattern is to identify the herd before approaching the owner.The former choice is to be recommended, notably in exploratory RA: when we are interested in analysing general livestock conditions in a given community or farming system (e.g., overall situation in the use of animal resources involving different animal species) clusters of households should be selected, preferably stratified according to income proxies (e.g., housing conditions, luxury goods ownership, etc.) or ethnic and cultural features. Also when land assets are not communal, it is recommended to identify clusters of households for investigating the livestock situation.

Alternatively, when we wish to focus the object of the analysis on selected livestock species, e.g., cattle, investigations can be carried out on clusters of herds which daily join together on communal pasture (the grazing units). Each grazing unit has to be considered as one herd. For example, in Ghibe Valley and in the Sidamo midlands of Ethiopia, one herd out of every five includes on average only one mating bull. If each herd is considered separate and not as part of a more complex unit, it would be difficult to understand not only the reproductive performance of the single herds, but also the choices of different farmers and the overall dynamics of the livestock system there (Ghirotti, 1988). The factors involved in the formation of such grazing units varies and its analysis can assist in understanding some social and productive features of that community. Some of the main factors are: ethnic or religious origins of the owners, location of the kraal, age/sex groups (calves may be herded separately near the village and milking cows may be given better pasture), fodder or herder availability. Where land is communal, the steps in selecting the herds are the following:

- estimate how many grazing units there are in the area,
- identify which are the criteria for their formation,

- decide which have to be studied on the basis of such criteria,
- analyse their composition,
- make a list of the livestock owners and
- interview some of the owners randomly selected if there are too many herds.

Individual farmers should be interviewed preferably at their homes using questionnaires. During such visits,selected indicators could be directly checked (housing conditions, land extension, single herd size and composition), verifying the collected information in a discreet way.

Some external specimens could be collected for further investigation (faeces, ectoparasites) and measurements performed (e.g., the milk offtake of some cows could be measured using a graduated jug, animal could be body-scored and their weight estimated through heart girth measuresments. At this stage of RA studies it is not advisable to approach animals too closely and insistently in order to avoid irritating farmers. A few selected case histories can be recorded on the spot to check answers and obtain more open answers from the farmers.

Because of the even greater importance of livestock in pastoral societies, interviews among nomadic and transhumant people should not focus on herd or flock sizes (information which could be obtained through periodical direct observations i.e., aerial surveys, counting and checking at watering, vaccination or dipping points) but rather on production dynamics (seasonal distribution of events such as calving or mortality, main reasons for offtake and culling) and qualitative informations, e.g., epidemiology of diseases, husbandry practices, nature of limiting factors to livestock exploitation. In agropastoral societies, excellent occasions for observation and verification are the visits to the grazing areas or farms.

9) Data analysis and interpretation of results.

The data obtained from the interviews should be analysed as soon as possible and results compared with the information obtained through the semi-structured interviews. Remarkable differences should be investigated, hypotheses for such diversities made and tested while the team is still on the site and discussions held at meetings with the farmers. Arithmetic means and rates could be easily calculated using pocket calculators. Moreover, modern computer technology allows utilization of laptops in which spread sheet software can be run. Herd projections can be carried out through rough "what if" analysis which makes use of the different productive parameters recorded. Comparisons between grazing units and households can be made converting the different size and species of animals into Tropical Livestock Units (TLU). A TLU is commonly taken to be an animal of 250 kg liveweight (Table I).

Table I: average TLU conversion factors for different species

species	TLU conversion factor
cattle[a]	0.7
sheep or goats	0.1
horses	0.8
mules	0.7
asses	0.5
pigs	0.2
chickens	0.01

[a]calves= 0.15

10) Feedback and discussion with the community.

The results of the appraisal, their different interpretations and possible solutions should be openly discussed in summing-up meetings with the farmers concerned, bearing in mind the potential target groups of the proposed supportive measures and different types of bias associated with such forms of discussion. The team should ensure that the picture of the livestock situation they obtained in a given area is not a misleading one, seeking confirmation and explanation of recorded data through community assistance.

11) Discussion of the results with central authorities and colleagues.

The answers gained through RA should lead to the identification and selection of practical activities already discussed with the concerned communities and local authorities. However, such solutions should be further discussed with the competent government authorities and potential donors. Just as little can be achieved at community level without informal leaders support, little can be achieved at central level without the support of government authorities and sometimes of academics

12) Dissemination of collected information.

Reports, workshops and discussions with colleagues or other officers involved in applied research and development programmes could be used to share information and discuss the results obtained. In such a way, it is possible to receive useful criticisms and suggestions both for further applied investigation and for programme formulation. At this stage, a project document can be formulated.

13) Research or development project phase.

As mentioned earlier, RA should aim at identifying practical activities

to improve living conditions (and in this case in making best use of animal resources) of the communities concerned. If responsible authorities approve them and resources are available, some activities identified by the team with the assistance of the community may be implemented. In such cases, the results of the earlier RA can provide a basis for further applied and better targeted studies and for the establishment of monitoring systems to assess the progress of planned activities.

14) Follow-up

If developmental or research activities are to be carried out, they should be monitored in time (e.g., during the implementation of the project) together with the parameters of herd dynamics, so that a more accurate picture of the changing situation can be drawn up with the farmers and activities corrected as needed. The RA should have shown the level of participation and confidence of local farmers toward researchers. If more confidence is progressively gained by farmers, more accurate sampling and measurements can be made, including direct contact with farmers' animals. In such a case, blood samples can be taken for different tests (i.e., immunological, microbiological or biochemical). The farmers who have proved to be collaborative can be involved in the study or in pilot project activities, and reasons for lack of interest from others can be investigated. Therefore, RA gradually becomes a tool to understand the community and then, with its assistance, to carry out activities which meet expressed needs and to evaluate results.

METHODS OF SUMMARIZING AND PRESENTING RA RESULTS

Several types of diagrams are widely used to summarize and present the collected information so that it can be discussed often already in the field. Besides histograms, bar, pie charts, and maps the most used ones are:

- transects where the most relevant features of the different areas and ecozones analysed are summarized, they are particularly useful in showing spatial differences and trends (fig. 1);
- seasonal calendars, occurrence and changes in human activities, production and biological events (including diseases) are plotted against climatic data; they can be useful in highlighting temporal patterns of phenomena (fig.2);
- flow diagrams and decision trees, the key factors which may influence decision-making and the conseguences derived from such decisions or other changes can be shown in such diagrams.

SOME SOURCES OF BIAS FROM RA TECHNIQUES

To investigate livestock means to investigate one of the most sensitive subjects for the farmer because of the fundamental socio-economic and cultural role played by animal resources in most traditional societies (Jankhe, 1982). Questions about his/her herd or flock size are very likely

	Highlands	Midlands	Lowlands
Soil	Illuvial clay	Fertile luvisols	Stony and sandy
Annual Rain Fall (mm)	600-1000	600-1400	200-600
Vegetation	Montane Forest	Evergreen Forest	Savanna
Average Plot size (ha)	1-1.2	0.5	1-1.5
Farming System	High potential cereal/livestock	High potential horticulture/livestock	Low potential cereal/livestock
Main Crops	Wheat, Barley, Enset	Enset, maize, coffee, chat, Fruits	Maize, Sorghum, cotton
Average Livestock holdings per Farm	1 horse 3 cattle 2 sheep	4 cattle 2 sheep 3 goats	6 cattle 4 sheep 2 goats
Average TLU per Farm	4	3.5	5
Cattle male/Female ratio	1/4	1/4	2/3
Constraints	Lack of services and communications	Population pressure, land scarcity	Erosion, water scarcity
Potentialities	Cereal production	Cash-crops development	Trade, soil conservation

Fig. 1 Transect of Sidama Awrajia (Ethiopia)

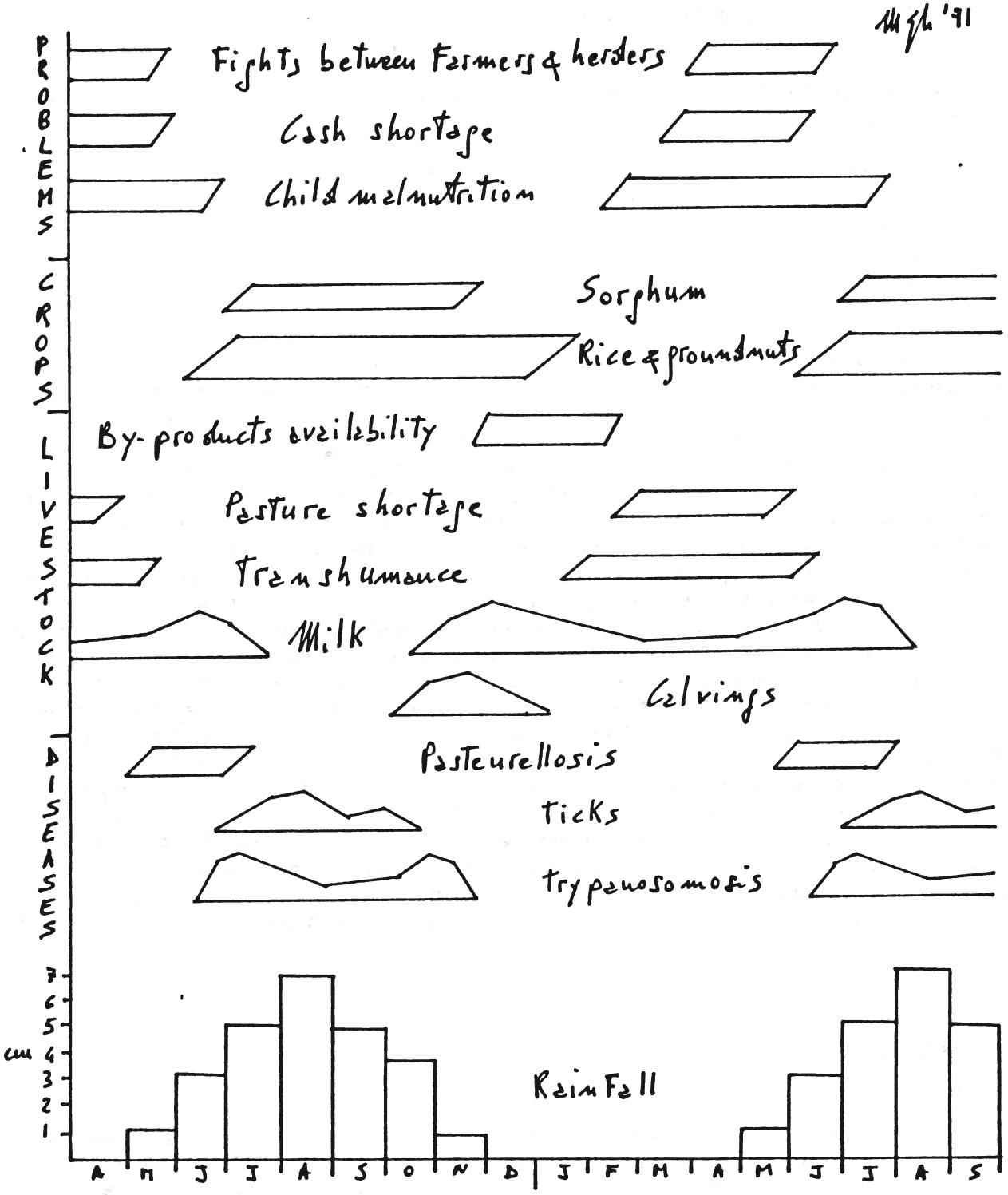

Fig. 2 Seasonal calendar of Boke' (Guinea)

to raise suspicion about future taxation or other unpleasant consequences: the analogy between a herd and a bank account in the industrial world is a common one. Therefore, the endorsement of the team in the community is the crucial point when performing RA in animal health and production. Community leaders can play a critical role as mediators and guarantee the confidential nature of RA, while explaining eventual benefits.

As previously discussed, some of the main methods to obtain primary data through RA are:

- direct observation, of selected indicators
- semi-structured interviews of key informants,
- individual interviews mostly through questionnaires on selected items,
- group interviews,
- workshops.

Errors associated with the use of questionnaires and direct observations have been analysed by Thrusfied (1986) and Putt et al. (1987). Bias can be reduced through careful and correct sampling and questioning. Because of the inevitable distortion arising from interview of a limited number of key informants, the information so collected should be checked and investigated using the other field techniques. The presence of outsiders influences local people's behaviour and responses which may be altered to please, confuse or deceive the researchers: the phenomenon known as "Heisenberg undertainty principle". Especially during group interviewing, expectations, may be aroused and answers may reflect more what people wish than what they know and think. In meetings, literate people and elites may receive more attention than the common farmers (Edgerton and Langness, 1977). On the other hand, some communities may live in fear and they may view outsiders as government officials. Therefore, they will avoid to openly express their opinions during public meetings or they may give wrong information. Mitchell and Slim (1991) argue that in developing countries interviewing faces kinds of two structural bias derived from western culture: expecting answers and "nutshelling". The first is the assumption that each question can have a very straightforward spoken answer. The second concerns the concept of brevity: we are accustomed to short questions and short answers. In many traditional societies brevity is not accepted and communication means talking about main events and phenomena rather than a number of brief questions and answers.

CONCLUSIONS

Because of their nature, mostly qualitative and using purposive sampling, rapid assessment methodologies are not a substitute for standard epidemiological techniques but they can be valid complements. Veterinary epidemiology has always benefited from the contribution of other disciplines. Its main scope is the study and control of factors jeopardizing better utilization of animal resources. Greater emphasis has been given in recent years to the management of available means, especially human resources, in disease control actions (Bainbridge and Sapirie, 1974; WHO, 1990). Social sciences like anthropology and sociology have provided useful methods and they have much in common with epidemiology. Social scientists

like epidemiologists are concerned with patterns. The former investigate cultural and organizational patterns within a community; the latter investigate patterns of diseases and other limiting factors within a population. Both deal with large numbers or groups and build their knowledge on field work. In development, rather than recording very accurate average values, we are more interested in comparing and identifying determinants which influence patterns and differences. Properly designed and investigated case studies in which different factors are systematically analysed may provide operative answers to practical problems and give information for the design of objective surveys. Nowadays, more often than in the past, veterinary epidemiologists are asked to work closely with other professionals in development activities and to provide practical solutions to straightforward problems. The use of field methods which take cognizance of the farmers's viewpoint and encourge collaborative work with the concerned community assists in such a difficult task.

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PREDICTIVE MODELS: APPLICATION OF NEW TECHNOLOGIES TO CLINICAL DECISION MAKING

A.T. CHAMBERLAIN*

The classical method of deriving predictive indicators, involving calculation of sensitivity and specificity parameters, were developed in the 1960's. At that time computational resources limited the types of predictive models that could be used and the choice was influenced more by this constraint than to select a model that met the clinician's requirements. The subsequent advent of widespread computational resources have altered the balance between ease of calculation and clinical requirements such that it is now possible to select models that satisfy the clinician's requirements with only scant regard as to the complexity of calculation. This paper reviews the clinical decision making process and derives a list of desirable features for any predictive model. Data related to the survival of adult horses with diarrhoea is used to investigate the performance of logistic regression, expert system and neural network models. It is hoped that the brief introduction to the methods used in this paper will encourage other workers to use such techniques in veterinary medicine.

THE CLINICAL DECISION MAKING PROCESS

Veterinary practitioners are frequently required to make decisions; diagnosing diseases, the diagnosis of physiological states such as pregnancy and predicting the prognosis of clinical cases under their care (Blood and Brightling 1988). In many cases the decision making process is complex with the practitioner working with incomplete information and attempting to combine quantifiable data (such as blood biochemistry) with unquantifiable information such as the owners attitude towards the animals and their financial capacity. At the same time the clinician is working within a compromise; attempting to maximise the accuracy of the decision reached whilst minimising the amount of resources committed to the decision making process.

The commonest form of clinical decision making is that of intuitive judgement and clinical experience (Blood and Brightling 1988) which is a highly subjective technique and thus not amenable to interfacing with mathematically derived models. A more rigorous method used by clinicians in human medicine is the hypothetico-deductive reasoning technique (Sackett *et al* 1985) and it is probably similarly popular in veterinary medicine (Pollock 1985). After an initial clinical and possibly para-clinical examination, the major or 'key' signs are identified. A list of diseases that show these signs are then drawn up and a probability attributed to each one. Although most clinicians do not allocate a specific probability value to each disease the traditional 'differential diagnosis' list is usually ranked in order of likelihood with labels such

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as 'rare', 'common', 'unlikely' etc. attributed to each disease. The attending clinician would then carry out further tests such as specific clinical examinations, biochemistry and haematology. The results of such tests will modify the probability of each disease on the list until one become dominant. Given that clinicians collect many pieces of information about a case before reaching a diagnosis it follows that any clinical predictive model should be multi-component in nature.

CLASSICAL PREDICTIVE MODELS

The classical method of clinical decision analysis assumes that the medical decision is dichotomous and so dichotomises the results of the test using a single cut-off point to determine the decision (Weinstein and Fineberg 1980). This type of test expresses the clinical value in terms of the sensitivity and specificity (Trajstman, 1979), often expressed as percentages in the range 0 to 100%. The importance of having a high sensitivity or high specificity will vary according to the prevalence of the disease in the population. In many cases the outcomes are of approximately equal probability such that the test efficiency as defined below may be of more value when comparing different tests.

Efficiency The probability of test correctly identifying an animal's status.

Limitations of the dichotomous method

The dichotomous method is of limited value both as a general method for deriving clinically useful indicators. Firstly the test produces a deterministic result, and perhaps more seriously only two predicted outcomes. Most medical tests are not dichotomous but have three decision choices; positive, negative and inconclusive. For example consider pregnancy diagnosis of cattle *per rectum* at six weeks *post coitus*. A dichotomous division with a high level of false negatives and positives would be undesirable; a method that used three decision options with a higher level of accuracy of prediction and a proportion of cases that cannot be predicted would be preferable.

The dichotomous decision model is in widespread use in human and veterinary fields for interpreting the results of tests such as the blood cholesterol and tuberculin test and has been the primary clinical decision model for several decades (Weinstein and Fineberg 1980). However it is rarely used in its true form; most tests have an intermediate, inconclusive area or use a secondary test to confirm an original, tentative diagnosis (eg. Tuberculosis testing in England and Wales). The favourable aspect of the dichotomous decision model is the ease with which the original model can be derived and with which it can be applied to cases in the field. In previous decades without widespread access to advanced computational facilities these two features were important but nowadays the ease of calculation are outweighed by the above mentioned disadvantages and alternative techniques are more appropriate.

DESIRABLE FEATURES OF A CLINICAL PROGNOSTIC INDICATOR

What then are the desirable features of a predictive model? Below are listed 10 factors that are considered desirable against which the models demonstrated in this paper can be judged.

Degree of accuracy required. To be of clinical value a predictor must correctly predict the outcome of a considerable proportion of all outcome groups with a high degree of accuracy. If

this is not the case then the clinical and economic value of obtaining the predictor will be limited.

Value of individual components. The measurement of each component of a predictor should be useful and interpretable in its own right.

Number of variables in model. The size of predictor model may be limited for two reasons

a) Certain types of model, such as logistic regression (Harrell 1983), may become sample specific when too many components are included such that they break down when applied to the parent population. It is therefore important to check that a predictor model is applicable to the population.

b) An increase in model components will result in an increase in the cost of using the model. Whilst the cost of any individual test is usually small relative to the cost of a mis-diagnosis the cost may be relevant indirectly. Expensive tests such as radio-immune assay and globulin fractionation require more expensive, specialist equipment and are therefore unavailable in the practice laboratory.

Applicability to different aetiologies. Many veterinary problems are defined in terms of their signs rather than the causal organism (eg diarrhoea, pneumonia, lameness, mastitis). It is therefore important that any predictive model should contain several components such that if a single component behaves atypically in any particular case its effect on the overall prediction will be small.

Accuracy of measurement of components. It should be possible to record accurately all components of a model which should be measured using widely available standards.

Clinical validity. Any clinically useful model must be able to cope with any errors that are likely to occur in the field and yet be able to respond to the expected ranges of component values that will be encountered.

Integration with other components of the decision making process. As discussed above the clinical decision making process works in terms of probabilities of certain outcomes rather than definite predictions. It follows that any predictive model that gives a probabilistic rather than a deterministic prediction is to be preferred. Deterministic predictors are incompatible with the clinical decision making process and therefore difficult to assimilate.

Applicability to cases outside the survey sample. Any predictor derived must be applicable to the parent population. Efron and Gong (1983) noted that any derived model will work best on the development data set and so it is desirable to test the model on an independent sample. In many studies this is not possible (Homser and Lemeshow, 1989) either due to the expense of collected an independent data set or because a new data set would not be directly comparable with the development set (Chamberless *et al*, 1990). Such difficulties in validating developed models has lead to the development of a range of validation techniques such as boot-strap and Jack-knife analysis (Efron and Gong, 1983). The requirement for validation will be considered in this paper using the technique of Jack-knife analysis.

Ease of calculation. Any predictor model must be presented in a form that can be easily assimilated and used by the clinician. In previous decades this has been of paramount importance; however with the advent of cheap micro-computers and advanced calculators it is

becoming less so. For example the current feeding standards for ruminants are almost incalculable manually (AFRC 1990).

Timing of the application of prognostic indicators. If predictor models are applied too early in a case's development then the range of possible aetiologies will be wide which may limit the accuracy of the predictive model. If applied too late then any prediction will be of limited clinical value because both clinician and stockman will have invested considerable resources in the case. However, given that a proportion of the predictions from any model will be equivocal it is important to be able to apply tests serially during the case's duration.

METHODS OF DERIVING PREDICTIVE MODELS

Logistic regression

Logistic regression was first used on medical data in 1967 (Truett *et al*) but has only been used widely over the past 3 - 5 years. It has been used to predict the risk of chronic heart failure (Chamberless *et al* 1990), the outcome of intensive care unit admissions (Lemeshow *et al* 1988) and the fate of children with Haemolytic Uraemic Syndrome (Kay and Little 1986). However, perhaps due to lack of specialist statisticians in the veterinary schools, it has not been used widely in veterinary medicine (Chamberlain, 1991). The logistic regression technique fits the logistic model to a single binary or ordinal variable (Harrell 1983). The generic prediction equation is shown below (equation 1 and 2). The end product from such an equation is a probability of a given outcome. The logistic regression formula used in this work is of the form :

$$p(D) = \frac{1}{1 + \exp(U)} \qquad \text{Harrell (1983) (1)}$$

Where : $p(D)$ = probability of dying

$$U = K + a_1 . b_1 + a_2 . b_2 + \ldots + a_q . b_q \qquad (2)$$

Where : K = intercept constant
$a_1 \ldots a_q$ = weighting assigned to each component
$b_1 \ldots b_q$ = q components in model

Logistic regression models may be derived by several means such as stepwise analysis or best-subset (all possible combinations) analysis (Chamberlain 1991). Stepwise analysis tends to find the single best model whereas best-subset analysis identifies a range of models with acceptable performance. Given that the derived models will be further assessed for their wider applicability best-subset analysis is preferable.

Expert systems

Expert systems are an attempt to incorporate the rule based decision making procedure used by many experts into a computer program (Forsyth, 1989). The rules are composed of statements separated by logic commands such as IF, OR, AND, NOT and THEN. A typical rule might be:

IF	time is 5.00 pm
AND	road is M25
THEN	road will be busy

Complex rules can be built up using several logic commands and mathematical comparators. Rules may be inter-dependent such that one rule uses the results of another rules to reach conclusions. Expert systems have been used in human medicine in the prescription of antibiotics, in agriculture for treating crop diseases and in veterinary medicine for treating piglet mortality (Vos *et al*, 1990). However few experienced experts think in terms of rigid rules as it generally results in an inflexible, 'by the book' approach; most think in a more liberal manner and use undefined rules. Obtaining a set of rules for a real-life problem is therefore difficult and has lead to the 'knowledge acquisition' block (Forsyth, 1989). To get around this block rule induction systems such as ID3 and AQ11 have been devised (Forsyth, 1989) that, given a series of examples, can derive a set of rules. A variant of the ID3 algorithm was used in this study (CRYSTAL, 1987) which identifies patterns within the data that best separate the outcome categories. If a sub-set of the data contains cases of more than one outcome further sub-divisions are identified until each sub-set contains only cases on one outcome. If the sample size becomes too small or a category contains mostly one outcome then further sub-division stops. The model is deterministic and predicts one of four results; lived, died, uncertain and unknown. Uncertain results are those that fit data patterns that had variable outcomes; unknown results are those whose data do not fit any of the patterns identified in the development set.

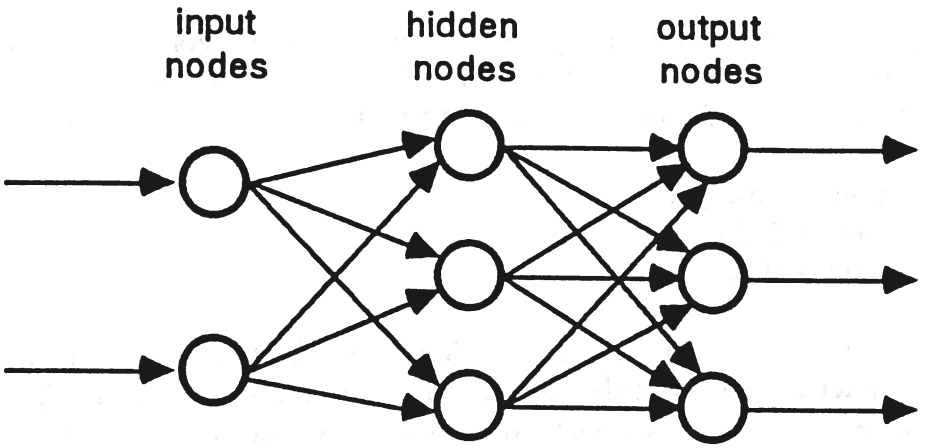
Limitations

Deductive algorithms based on ID3 do not work well with numerical data in that they fail to recognise the continuous distribution and devise a separate rule for each case in the developement data set. To overcome this it is necessary to categorise the data into discrete categories. This results in much of the information being lost and the continuous distribution being replaced by a step-wise categorical distribution.

Neural Networks

Neural networks are, as the name implies, considered to be based around the structure of biological neurons and their inter-connections (McClelland and Rumelhart (1988). A simplified structure of a neural network is shown in figure 1 where three 'layers' of 'nodes' are interconnected by 'vectors'. The number of input nodes is equal to the number of independent variables in the 'model' and the number of output nodes the number of dependent variables (usually one). There may be several layers of hidden nodes in between the input and the output and any number of nodes within the hidden nodes.

Fig 1 Structure of a simplified neural network.



There is great uncertainty about the number of hidden layers and the number of nodes within each layer. The networks used in this study have a single hidden layer with the number of nodes set at the average of the input and output layer size. The values of the vectors represent the 'programming' of the network and thus it is the connections between the nodes that carry the information. The input to a node is the sum of all the input vectors plus a bias value. The output from a node to the next layer is calculated from the logistic function as follows:

$$\text{Vector.out} = 1/(1+e^{\text{vector.in}}) \quad (3)$$

(McClelland and Rumelhart (1988)

Initially all the vectors are set a random numbers and the biases are set to zero and the model 'learns' from the data set presented. The vector weights and node biases are repeatedly modified using a back-propagation technique until the sum of the predictive errors is less than a pre-determined amount. Neural networks are a very young science and to date have largely been used in simple tasks such as alphanumeric character recognition (Hirose *et al*, 1991) where a pattern is known to exist. Neural networks have only recently become widely available due to the large computer resources needed - a test data set of 66 cases may require a million iterations to reach a solution. Results are reported in terms of probabilities with predictions being made for all cases considered.

Few limitations have been reported in the use of neural networks but little work has been carried out on such factors as wider applicability of derived models, effect of noisy input data etc. However, due to the connectionist nature of the pattern storage, it is not possible for humans to interpret how the model deduces the outcome of cases unlike expert systems where the rules can be inspected, understood and incorporated in the clinician's own desision making process. The total 'black box' nature of neural networks is seen as a limitation by many users and requires that derived models are extensively validated before use.

ASSESSMENT OF MODEL PERFORMANCE

It is important that any derived predictive model is validated. Initially this can be carried out on the developement data set but ideally it should be extended to include external data sets.

Application to developement data set

Of the three methods described above it is only possible to attribute a level of significance to the logistic regression. However using a 50% probability cut-off point the efficiency of prediction can be calculated as follows

$$EFF_{50}\,(\%) = \text{Efficiency} = 100 \,.\, (a+d) \,/\, N \qquad (4)$$

Where
- a — number of cases correctly predicted as living
- d — number of cases correctly predicted as dying
- N — Total sample size

A 50% cut-off is not ideally suited for use in assessing clinical tests in that it does not differentiate between a probability of living of 0.55 and of 0.99 - both will be taken as predicting an outcome of 'lived'. Therefore it is proposed that additional 'efficiency' measurements be calculated using 75% and 90% cut-off points where appropriate.

Validation against external data sets

Derived models will always perform in an optimistic manner when applied to the development data set. Where the derived model is used to make future predictions then it is important that the model is externally validated (Efron 1986). If a second independent data set is available then this can be used but often this is not possible. In such cases alternative methods must be devised. A range of informal and exploratory techniques for external validation have been derived such as Jack-knife analysis (Efron and Gong 1983) and can be applied to any function of n independent variables. The technique attempts to mimic the introduction of new cases by omitting one case at a time from the sample, re-deriving the logistic regression model and predicting the outcome of the omitted case. This is performed for each case in turn such that the overall accuracy of predicting all the omitted cases can be assessed. The technique requires that the cases can be considered as having been collected at random and that they are independent such that any omitted cases can be considered as a 'new' case. Omitting cases singly results in numerous re-derivations of the predictive model and unless highly automated can be very time consuming. To facilitate the analysis it is possible to repeatedly exclude random sub-sets from the data. Efficiency of prediction values with different cut-off levels can be calculated as described above and by comparing such statistics from the original and Jack-knife analysis one can derive an assessment of the model's degradation as follows:

$$DEGR = [\ 1 - (P_{JK} \,/\, P_{IN})\ ] \times 100 \qquad (5)$$

Where
- P_{JK} = Predictive efficiency of Jack-knife analysis results
- P_{IN} = Predictive efficiency of initial predictive method

This will give a percentage value with a low percentage indicating a small extent of degradation and hence a more robust model. It is possible to derive degradation figures for each of the cut-off points which can be referred to as $DEGR_{50}$, $DEGR_{75}$ etc.

APPLICATION OF THE PREDICTIVE TECHNIQUES DESCRIBED

Demonstration data set

Case history, biochemical and haematological data collected from adult horses with diarrhoea were kindly made available by Dr P J Cripps (Bristol University Veterinary School) for use in this study. The data collected were determined by experienced equine clinicians to reflect what they and the literature regarded to be relevant in determining the prognosis of adult horses with diarrhoea (Mair *et al*, 1990). Data (16 variables) for 66 horses were collected (44 lived, 22 died). Diagnosis as to cause of diarrhoea was made in 23 (35%) cases and of these 9 were at post-mortem. Eight different diseases were diagnosed. White blood cell counts were corrected for packed cell volume and enzymes log (base 10) transformed to give a more Normal distribution. The outcome variable was scored as zero or one with one representing death. Association with the outcome was then assessed using the t-test and Chi square test as appropriate (table 1).

Table 1. Association between case outcome and measured variables using the t-test and Chi square test as appropriate (total n = 66, lived n = 44, died n = 22).

Variable	Code	Lived Mean	Lived SD	Died Mean	Died SD	P value	
Age	AGE	10.6	6.48	11.6	8.37	.66	
Breed of horse	BREED					.07	a
Sex	SEX					.4	
Packed cell vol	PCV	38.1	5.53	43.2	8.56	.017	a
Total protein	TPROT	63.2	10.8	58.9	17.8	.31	
Log_{10} albumin	LOGALB	33.9	7.92	25.5	10.2	.0017	a
Corr[b] WBC	CWBC	20.3	9.89	25.6	13.9	.12	a
Corr Neutrophils	CPMN	11.3	6.33	16.7	9.3	.02	a
Corr lymphocytes	CSL	7.3	2.84	6.9	5.4	.72	
Corr Eosinophils	CEO	.7	1.26	.4	.51	.31	
Corr Basophils	CBAS	.2	.79	.2	.64	.99	
Log_{10} Urea	LOGUREA	.7	.14	.7	.19	.53	
Log_{10} SAP	LOGSAP	2.6	.18	2.9	.25	.0001	a
Log_{10} AST	LOGAST	2.5	.21	2.5	.26	.53	
Log_{10} gamma-GT	LOGGGT	1.3	.31	1.4	.41	.58	

a used in logistic regression 'best-subset analysis'.
b Corrected for packed cell volume.

Logistic regression

From table 1 six variables were identified as being associated at the 0.3 level or better. The horse breed was coded as a number ranging from one to five but such a variable could not be treated as a continuous variable and so was further transformed. Table 2 shows the animals fate sub-divided by breed. It can be seen that breed categories one and two had a good prognosis (87% and 90% survival) whereas the other breeds had an equivocal prognosis (55%, 45% and 66%). Therefore breed groups one and two were combined into one category and groups three, four and five into a second category.

Table 2. Outcome sub-divided by breed.

		Breed				
		1	2	3	4	5
Lived		13	9	15	5	2
	(%)	87	90	55	45	66
Died		2	1	12	6	1
	(%)	13	10	44	54	33

Previous work (A.T. Chamberlain, 1991) has suggested that better prognostic models are derived when the direction of association between the outcome and all the model components are the same - that is to say the regression lines of each of the variables against the outcome slope the same way. The breed categories were reversed and the albumin variable values multiplied by minus one such that all the slope co-efficients were then positive.

All triple, double and single combinations of the six factors associated with the case outcome (table 1) were subjected to logistic regression in a best subset analysis resulting in 41 analyses. Thirteen models were identified (table 3) where EFF_{50} exceeded 75% and an EFF_{75} exceeded 55%, and were subjected to Jack-knife analysis with single cases being excluded at each run. The efficiency of prediction and degradation figures for the Jack-knife analysis are given in table 4.

Results

Table 3 Composition and efficiency of prediction (%) of 13 'best' models identified by best sub-set analysis

Model factors			EFF_{50}	EFF_{75}
BREED	LOGSAP		77	56
LOGALB	LOGSAP		85	55
CPMN	LOGSAP		79	54
BREED	PCV	LOGSAP	79	58
BREED	LOGALB	LOGSAP	85	60
BREED	CWBC	LOGSAP	76	55
BREED	PMN	LOGSAP	74	56
PCV	LOGALB	CPMN	85	56
PCV	CWBC	LOGSAP	86	58
PCV	CWBC	LOGSAP	79	56
PCV	CPMN	LOGSAP	80	59
LOGALB	CWBC	LOGSAP	81	55
LOGALB	CPMN	LOGSAP	83	57
Average			80.7	56.7

Table 4 Composition, efficiency (%) and degradation of prediction (%) of 13 'best' models when subjected to Jack-knife analysis

Model factors			EFF_{50}	EFF_{75}	$DEGR_{50}$	$DEGR_{75}$
BREED	LOGSAP		76	56	2	0
LOGALB	LOGSAP		82	59	4	-6
CPMN	LOGSAP		68	58	13	-6
BREED	PCV	LOGSAP	74	62	6	-6
BREED	LOGALB	LOGSAP	79	58	7	4
BREED	CWBC	LOGSAP	74	56	2	-2
BREED	CPMN	LOGSAP	73	59	2	-5
PCV	LOGALB	CPMN	80	56	5	0
PCV	CWBC	LOGSAP	80	62	7	-7
PCV	CWBC	LOGSAP	79	56	0	0
PCV	CPMN	LOGSAP	79	61	2	-3
LOGALB	CWBC	LOGSAP	82	61	-1	-9
LOGALB	CPMN	LOGSAP	82	62	2	-9
Average			77.5	58.9	3.9	-3.8

Discussion

In general the logistic regression models achieved poor levels of predictive accuracy particularly at the 75% confidence level where only one model achieved 60% accuracy. Considering that the prior probability of a given outcome was 33 or 66% this would generally be unacceptable clinically. However the results for the jack-knife analysis indicate that the models' performance does not degrade much (average 4%) and actually improves at the 75% confidence level. The largest model considered only contained three variables so atypical changes in a single variable could have a considerable effect on the predicted outcome. Work with data on the downer cow has shown (Chamberlain, 1991) that as model size increases degradation also tends to increase. The negative degradation values for $DEGR_{75}$ indicate that the models performed better on Jack-knife analysis than on the original data. Such results are difficult to explain and, as it has not been seen in the analysis of other data sets (Chamberlain, 1991), warrant further investigation.

Expert systems

Because the expert system induction system used in this work behaves poorly with numeric data the Normalised data for the blood biochemistry and haematology were transformed into seven categories using the ranges shown in table 5.

Table 5. Standard deviation ranges used to convert Normalised blood biochemistry and haematology data into categories.

Category	Range (S.D.'s)		% Normal
	Lower	Upper	Population
Extremely Low	-10.0	-2.500	.6
Very Low	-2.5	-1.500	6.1
Low	-1.5	-.4999	24.2
Average	-.5	.4999	38.3
High	.5	1.4999	24.2
Very high	1.5	2.4999	6.1
Extremely high	2.5	10.0	.6

The initial model contained all 15 variables listed in table 1. Examination of the variables used in each case to determine the predicted outcome showed that eight variables were not used for any of the cases considered and two others for less than 10% of the cases considered. Such variables were removed from the model and a five component model was derived. To obtain models with fewer components the least used component was dropped and the model re-run resulting in a four component and a three component model being considered. In the three component model the three variables were used in 68%, 83% and 97% of the cases and so further variables were not dropped. The predictive efficiency of the four models considered is shown in table 6. Jack-knife analysis was carried out by omitting 11 randomly selected cases from the data on six occasions and re-deriving the expert system model for each set of 55 cases. Each model was then used to predict the outcome of the 11 cases omitted and the predictive

accuracies summed over the six sets of results.

Results

The need to categorise the numerical data prior to analysis resulted in considerable loss of information. Efficiency of prediction was maximal for the four and five component models and declined slightly with increased model size and considerably with reduced size but was generally adequate (>90%) for all models containing more than three variables.

Table 6 Efficiency of prediction (%) of different sized expert system models and percent of inconclusive predictions.

No factors in model	EFF	Inconclusive
15	91	2
5	98	0
4	98	2
3	64	36

Table 7 Efficiency of prediction (%) of different sized expert system models after Jack-knife analysis and percent of inconclusive predictions.

No factors in model	EFF	Inconclusive	Degradation
15	57	5	37
5	74	9	24
4	65	11	34
3	50	33	22

Discussion

The reduced efficiency for the three component model was because the three variables did not contain sufficient information to correctly categorise all of the presented cases resulting in increased numbers of inconclusive predictions. When subjected to Jack-knife analysis efficiency of prediction was maximal for the five component model and decreased with increasing and decreasing size. The reduced efficiency in the 15 component model may have been because the model contained too much information leading to memorisation of the data rather than pattern recognition with subsequent poor performance on the 'external' cases. The reduction of predictive efficiency as model size fell below 5 variables may have been because the data did not contain sufficient information for all the data patterns to be identified. Many of the 'new' cases did not fit the learnt patterns and so the number of inconclusive predictions increased.

There would appear to be an optimum model size for induced expert systems; too large and the

model memorises the data rather than recognises patterns, too few and there is insufficient information to allow all the patterns to be differentiated.

Neural Networks

An initial model containing all fifteen variables (table 1) was used to derive a neural network. To assess the relative importance of each component in the model the sum of the absolute values of the output vectors from the input nodes was determined (figure 1). The input node (component) with the smallest total was considered to be having least effect on the network and was dropped from the subsequent model. The importance of each input node was re-assessed after each run and further components were dropped until a two component model was obtained. The predictive efficiency of the fourteen models considered is shown in table 8. Jack-knife analysis was carried out by omitting 11 randomly selected cases from the data on six occasions and re-deriving the expert system model for each set of 55 cases. Each model was then used to predict the outcome of the 11 cases omitted and the results summed over the six runs. The Jack-knife results are shown in table 9.

Table 8 Analysis of prediction efficiency of 14 models applied to test data.

No vars in model	EFF_{50}	EFF_{75}	EFF_{90}
15	100	100	100
14	100	100	100
13	100	100	100
12	100	100	100
11	100	100	100
10	100	100	100
9	100	100	100
8	100	100	100
7	100	100	100
6	100	98	94
5	100	100	95
4	100	100	97
3	100	0	0
2	100	0	0

Discussion

The predictive efficiency of the neural networks derived was extremely high. All models containing more than six variables correctly predicted the outcome of all cases considered with more than 90% confidence. Only when model size falls below 4 components does EFF_{90} fall below 90%. The Jack-knife analysis degradations were higher than for the logistic regression suggesting that the models derived were more sample specific. However the EFF_{90} for the jack-knife analysis exceeded 70% for most of the models containing four or more components and

EFF_{50} exceeded 85%. Jack-knife analysis efficiencies for the largest models were slightly less than the results for smaller models suggesting that such models may have memorised the data set to a greater extent. Again very small models (less than 4) appear to contain in-sufficient information to correctly predict case outcomes.

Table 9 Efficiency of prediction and degradation of prediction of 14 neural network models after jack-knife analysis

	JACKKNIFE			DEGRADATION		
no vars in model	EFF_{50}	EFF_{75}	EFF_{90}	$DEGR_{50}$	$DEGR_{75}$	$DEGR_{90}$
15	82	76	74	18	24	26
14	84	77	72	16	23	28
13	88	92	73	12	8	27
12	88	78	73	12	22	27
11	88	82	74	12	18	26
10	85	78	73	15	22	27
9	88	78	74	12	22	26
8	88	74	69	12	26	31
7	96	80	74	4	20	26
6	88	74	70	12	25	25
5	88	81	80	12	19	16
4	93	80	73	7	20	25
3	59	24	0	40	0	0
2	76	11	0	24	0	0

CONCLUSIONS

Of the three methods considered in this work the two artificial intelligence methods seem superior to the statistical approach. In both artificial intelligence systems there are indications that there is an optimal model size for maximal predictive efficiency. Too large a model results in so much information being presented that the model tends to memorise rather than learn the data; too little data and there is insufficient information for the models to be able to learn the patterns sufficiently well to be able to classify further cases.

Whilst the neural network method achieved considerably better results it is impossible to examine the method of prediction in such a way that generalisations can be drawn. By contrast the expert system model produces models that can be examined by expert clinicians and possibly interpreted in terms of the case pathology. However to what extent the derived rules are artifacts and to what extent they reflect the underlying aetiology of the disease is uncertain. The inability to determine how neural networks achieve their predictions is at first sight disconcerting until one realises that it is similarly difficult to determine how many human experts reach their predictions!

The work presented here has assumed that all the incoming information is perfect, in that it contains no 'noise'. Further work is needed to determine how the models discussed cope with recording and measurement errors that occur in clinically derived data. However it is hoped that sufficient results have been presented to demonstrate that such techniques may be of use to helping to make clinical decisions.

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SOCIETY FOR VETERINARY EPIDEMIOLOGY AND PREVENTIVE MEDICINE

APPLICATION FOR MEMBERSHIP

Name .....

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I wish to be elected to membership of the Society for Veterinary Epidemiology and Preventive Medicine.

Signed .....

Date .....

INTEREST GROUPS

Please tick the appropriate boxes to indicate your interests:

- ☐ Computing, including data-logging
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- ☐ Disease nomenclature and epidemiological terminology
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Please send this form to the Society's Secretary:

Dr K.S. Howe
Agricultural Economics Unit
Economics Department
University of Exeter
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The annual subscription is £10.

SOCIETY FOR VETERINARY EPIDEMIOLOGY AND PREVENTIVE MEDICINE

CONSTITUTION AND RULES

NAME

1. The society will be named the Society for Veterinary Epidemiology and Preventive Medicine.

OBJECTS

2. The objects of the Society will be to promote veterinary epidemiology and preventive medicine.

MEMBERSHIP

3. Membership will be open to persons either actively engaged or interested in veterinary epidemiology and preventive medicine.

4. Candidates for election must return a completed application form. The Secretary will then circulate the names of candidates on the agenda for the next general meeting. Election of candidates will be by a simple majority vote of members present at the general meeting.

5. Non-payment of subscription for six months will be interpreted as resignation from the Society.

OFFICERS OF THE SOCIETY

6. The Officers of the Society will be President, Senior Vice-President, Junior Vice-President, Honorary Secretary and Honorary Treasurer. Officers will be elected annually at the Annual General Meeting, with the exception of the President and Senior Vice-President who will assume office. No officer can continue in the same office for longer than six years.

COMMITTEE

7. The Executive Committee of the Society normally will comprise the officers of the Society and not more than four ordinary elected members. However, the Committee will have powers of co-option.

ELECTION

8. The election of office bearers and ordinary committee members will take place at the Annual General Meeting. Ordinary members of the Executive Committee will be elected for a period of three years. Retiring members of the Executive Committee will be eligible for re-election. Members will receive nomination forms with notification of the Annual General Meeting. Completed nomination forms, including the signatures of a proposer, seconder, and the nominee, will be returned to the Secretary at least 21 days before the date of the Annual General Meeting. Unless a nomination is unopposed, election will be by secret ballot at the Annual General Meeting. Only in the event of there being no nomination for any vacant post will the Chairman take nominations at the Annual General Meeting. Election will be by simple majority of members voting at the Annual General Meeting. Tellers will be appointed by unanimous agreement of the Annual General Meeting.

FINANCE

9. An annual subscription will be paid by each member in advance on the first day of May each year. The amount will be decided at the annual general meeting and will be decided by a simple majority vote of members present at the annual general meeting.

10. The Honorary Treasurer will receive, for the use of the Society, all monies payable to it and from such monies will pay all sums payable by the Society. He will keep account of all such receipts and payments in a manner directed by the Executive Committee. All monies received

by the Society will be paid into such a bank as may be decided by the Executive Committee of the Society and in the name of the Society. All cheques will be signed by either the Honorary Treasurer or the Honorary Secretary.

11. Two auditors will be appointed annually by members at the annual general meeting. The audited accounts and balance sheet will be circulated to members with the notice concerning the annual general meeting and will be presented to the meeting.

MEETINGS

12. Ordinary general meetings of the Society will be held at such a time as the Executive Committee may decide on the recommendation of members. The annual general meeting will be held in conjunction with an ordinary general meeting.

GUESTS

13. Members may invite non-members to ordinary general meetings.

PUBLICATION

14. The proceedings of the meetings of the Society will not be reported either in part or in whole without the written permission of the Executive Committee.

15. The Society may produce publications at the discretion of the Executive Committee.

GENERAL

16. All meetings will be convened by notice at least 21 days before the meeting.

17. The President will preside at all general and executive meetings or, in his absence, the Senior Vice-President or, in his absence, the Junior Vice-President or, in his absence, the Honorary Secretary or, in his absence, the Honorary Treasurer. Failing any of these, the members present will elect one of their number to preside as Chairman.

18. The conduct of all business transacted will be under the control of the Chairman, to whom all remarks must be addressed and whose ruling on a point of order, or on the admissibility of an explanation, will be final and will not be open to discussion at the meeting at which it is delivered. However, this rule will not preclude any member from raising any question upon the ruling of the chair by notice of motion.

19. In case of an equal division of votes, the Chairman of the meeting will have a second or casting vote.

20. All members on election will be supplied with a copy of this constitution.

21. No alteration will be made to these rules except by a two-thirds majority of those members voting at an annual general meeting of the Society, and then only if notice of intention to alter the constitution concerned will have appeared in the notice convening the meeting. A quorum will constitute twenty per cent of members.

22. Any matter not provided for in this constitution will be dealt with at the discretion of the Executive Committee.

April, 1982
Revised March, 1985; April, 1988