SOCIETY FOR VETERINARY EPIDEMIOLOGY AND PREVENTIVE MEDICINE

Proceedings of a meeting held at the University of Glasgow on the 27th, 28th and 29th of March 1996

Edited by M.V. Thrusfield and E.A. Goodall

ISBN 0 948073 24 1

ACKNOWLEDGEMENTS

The following companies provided financial support for the conference and for publication of these proceedings:

Glasgow Development Agency

Grampian Pharmaceuticals

Hoechst UK Limited

Mallinckrodt Veterinary Limited

Moredun Foundation

Scottish Agricultural Colleges Veterinary Services

Scottish Enterprise

University of Glasgow Veterinary School

ECONOMICS

COMBINING ECONOMIC ARGUMENTS AND ACTIVE SURVEILLANCE TO PROMOTE BETTER MANAGEMENT OF ENDEMIC CATTLE DISEASE

GEORGE J. GUNN[1] AND ALISTAIR W. STOTT[2]

A fresh approach to the management of endemic cattle disease was required in the Highlands and Islands of Scotland. During 1992 the Scottish Agricultural College's Veterinary Services and Agricultural and Rural Economics department have combined forces in a new initiative to promote preventive health programmes among the cattle farmers of the region. This paper describes the results for the first phase of the cattle health programme. The questionnaire responses of the farmers and veterinary surgeons involved are also described. The discussion considers developments within the existing programme in the light of such feedback and also considers the merits of this new approach to disease control.

The cattle health programme in the Highlands and Islands of Scotland takes the form of an educational programme, promoting preventive medicine strategies using economic arguments which are derived from local surveillance data. This programme has its roots in a cattle health scheme study commissioned by The Highlands and Islands Enterprise Company (HIE) from the Scottish Agricultural College (SAC) in 1990. The conclusions of that study included the suggestion that, in the veterinary field, an education programme aimed at motivating cattle producers to adopt preventive health programmes might be the best approach to optimising farm production and incomes. This was in contrast to the HIE's preferred option of eliciting premiums in the market place through the sale of calves with a guaranteed health status.

To put this into context it must be appreciated that most cattle are sold out of the area as 'stores' for fattening from single-suckled beef farms. Very few farmers go on to fatten their own calves and even fewer specialise in purchasing and fattening calves through to slaughter weight. Other important features at the time were the emergence of BSE (Bovine Spongiform Encephalopathy) as a serious and potentially long term barrier to the export of cattle and cattle products; in particular undermining a lucrative market in pedigree breeds such as Highland Breed and Belted Galloway. The imposition of beef cow quotas had, in addition to the earlier dairy cow quotas, limited the potential to increase farm incomes through expansion of herds. Media reports indicated that the number of beef and dairy herds in the region were declining.

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The HIE cattle health scheme study included a survey of every large animal veterinary practice in the region to try and determine which were the most important diseases of cattle. A scoring system established that calf enteritis was, in the view of the veterinary surgeons, the most important problem among the beef herds. The next most important condition was considered to be calf pneumonia. SAC Veterinary Services staff working with colleagues from the Agricultural and Rural Economics department were certain that in many cases where a serious outbreak of either of these generic calf diseases occurred then the resultant economic impact on the farm seriously threatened already precarious farm incomes.

SAC were also aware that the veterinary practices despaired of ever succeeding in the widespread promotion of preventive health programmes within the suckled beef herd. Frustratingly it was concluded that there were frequently many measures which would, if introduced, help in many situations. Unfortunately the study had also established the problem later described by others (Leonard et. al., 1993) (Caldow et. al., 1993) that there were no existing sources providing reliable data to describe the incidence of endemic bovine diseases and that only sparse information was available about the cost of these conditions at farm level.

The Highland Region of Scotland, as a less favoured area, was subsequently awarded Objective 5b Status within the EEC. The perception was that the rural communities and their economies were seriously threatened and upland and marginal farms (beef and sheep) were suffering economic hardship. Funding was made available to try and improve cattle health but this had to be through education and could not take the form of a production subsidy. The EEC were intent upon trying to support the rural economy and small businesses throughout the region and one of their objectives was to promote animal health and welfare. SAC therefore undertook to try and establish the educational programme recommended in their earlier report.

METHODS

SAC adopted an underlying theme of improving farm incomes through the reduction in losses through disease. After considerable discussion a veterinary practice based system was selected since the farmer/veterinary surgeon 'team' was the unit which we were hoping to promote in the battle against bovine disease. The focus of our programme was on endemic health and production problems. The challenge was to present the information to the farming community in a way which would motivate them to adopt preventive health programmes and abandon the ambulance approach to veterinary medicine. Eventually it was determined that an economic Cost-Benefit argument would be most likely to succeed, particularly if local disease outbreak data were included. The cattle health programme had to include the generation of such a dataset.

Five cattle orientated veterinary practices, geographically close to Inverness, agreed to participate in the first phase of this study. Data collection was based upon questionnaires which were completed by the veterinary surgeons involved. A two-tier system was adopted; outbreaks were identified (recording basic outbreak details) using preliminary surveillance questionnaires. Then at the end of the surveillance period an outbreak summary questionnaire was used to summarise all the details of the outbreak. The preliminary surveillance questionnaire was divided into two sections, one identifying outbreaks by farm visits and animal examination and the other identifying outbreaks by drug sales where no animal examination had taken place. Only one disease was targeted by a veterinary practice at any time, with a minimum surveillance period of ten weeks. The problem time period for diseases such as calf scour varied by veterinary practice and were dependent upon factors such as calving season, local calving patterns, altitude and weather conditions. An outbreak was defined as one or more morbid calves. The study denominator for phase one veterinary practices was determined as 513 herds during the first year falling to 509 in the second year and included 23 dairy herds.

Calculation of economic results

Details of the calculations and associated assumptions used to establish the cost of enteritis are given by Stott and Gunn, 1995. The loss in calf value was based on a sliding scale of reduced weight and price at sale according to whether the veterinarian judged the outbreak to be slight, moderate or severe. Mortality was fixed at £130/calf. Veterinary costs were the sum of all drugs used, call out charges, veterinarian's time charged for in addition and any other expenses reported such as laboratory tests etc. Rates used were those supplied by the practice concerned. The opportunity cost of farm labour was taken as £1/hour using fixed hourly rates of 0.5 hour/day/morbid calf, 0.5 hours per day overhead time and 14 hours per dead calf for fostering a replacement. The opportunity cost of capital was the total cost (ex labour) charged at 10% for 6 months.

For pneumonia, calculations and assumptions were similar to those for enteritis. Enteritis however was confined to young calves. Pneumonia affected cattle of all ages. For this reason, additional costs were included to represent the drop in throughput of cattle per unit time and the extra feed consumption due to delayed marketing of morbid animals.

RESULTS

The overall incidence of calf pneumonia during the winter of 1992/3 was found to be 28% with a range between 6% and 43% dependent upon veterinary practice. The overall incidence for calf enteritis was found to be 33% with a practice range between 26% and 41%.

Presentation of economic results

A series of 10 veterinary practice meetings were held during 1993/4 to present the cattle health programme results to the farming communities involved. A decision analysis framework (Boehlje & Eidman, 1984) was used to present the economic information. This emphasised the need for an appropriately informed choice to be made between alternative disease control strategies.

Three main themes were adopted. First the total cost of disease control was presented for the practice concerned and compared with the overall mean (Table 1). This gave an indication of the relative extent of the problem for the practice.

Table 1 Estimated total cost of disease in Phase 1 (£ per calf at risk)

Practice Number:	Pneumonia	Enteritis
1	14	58
2	20	7
3	28	20
4	28	39
5	13	42
Overall	22	32

Next, the variability of total cost was demonstrated (Figure 1). This emphasised the importance of risk. As the distribution of total cost is skewed, the probability of a low cost outbreak must be balanced by a consideration of the possibility of an outbreak costing much more than the average cost.

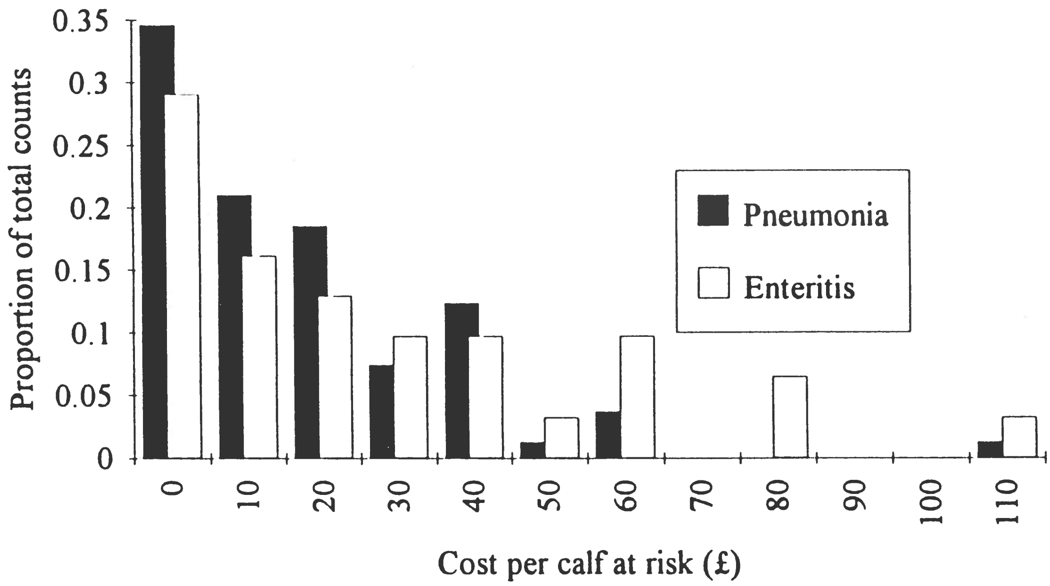

Fig 1. Distribution of total cost for Phase 1 Enteritis and Pneumonia surveys

Finally, a breakdown was given of the percent contribution of each component of the disease cost calculation to the total cost (Table 2).

Table 2. Percent contribution of each component to the total cost in phase 1

	Pneumonia	Enteritis
Loss in calf value	n/a	18
Mortality	14	16
Drop in throughput	22	n/a
Extra feed	18	n/a
Drugs	28	13
Vets time plus incidentals	6	3
Farm labour (opportunity cost)	8	47
Capital (opportunity cost)	4	3

Audience feedback from the presentations

A sample of 27 farmers returned a postal questionnaire following the series of meetings on pneumonia in 1994. The respondents were asked to give their overall opinion of the meeting on a scale from 5 (very good) to 1 (very poor). Their average score was 4.2 with the lowest rating being 3 (average) given by 2 respondents. Of these respondents, 8 had also attended an enteritis meeting in 1993 and were therefore able to rate this at 4.4 with only one score of 3.

Each talk consisted of three separate sections. The first section was a talk about the calf pneumonia survey results and the different agents involved. The second section featured the cost of pneumonia outbreaks. The final section gave information about the control and prevention of calf pneumonia. The respondents were asked to rate each section according to how interesting it was and also how informative (learning new facts). Possible ratings were either 3 (very interesting/informative), 2 (quite interesting/informative), or 1 (not interesting/informative). The results of this part of the survey are given in Table 3.

Table 3. Count of feedback scores for each section of the pneumonia talks in 1994

Score	Section 1: Interest	Information	Section 2: Interest	Information	Section 3: Interest	Information
1	0	0	2	2	0	1
2	13	13	13	18	11	11
3	12	12	10	5	14	13

Although all sections gained high scores, a chi-squared test revealed that it is likely that respondents found section 2 (costings) less informative than section one (agents) ($p<0.06$). There were insufficient grounds to reject the null hypothesis under any other comparison.

The questionnaire also revealed that 7 respondents found the handout associated with the talk very valuable, a further 19 rated it quite valuable, none of the respondents felt that it was of no value. The style of meeting as described above was either rated much better (5), better (14) or similar (2) to the traditional veterinary practice meeting. Only one rated the style poor compared to a traditional meeting. All respondents bar one, said that they will concentrate more on prevention of calf pneumonia as a result of this meeting.

The veterinary practitioners were also surveyed after the talks. Their comments suggest that they found the talks even more interesting and informative than did their clients. One suggested that it was interesting for the vets but may have 'lost' the farmers. All felt that the talks would help promote preventive veterinary medicine.

DISCUSSION

The wide range of incidence of both diseases between years and between practices together with the wide range in the costs of the diseases between practices illustrates the importance of providing individual advice on disease prevention and control. Both farmers and veterinarians questioned, confirmed that the local information provided here was a valuable adjunct to local experience. By introducing the concept of expected value (cost of disease weighted by the probability of an outbreak) it is possible to combine the information on local levels of incidence and disease cost in order to support decision making on disease prevention and control. For example, the expected value of disease can be compared with the cost of using a vaccine. The use of this and other methods of decision analysis is reviewed in this context by Bennett (1992). Experience with the farmers' meetings here suggests that the expected values technique may be better adopted by veterinarians on behalf of their farming clients. The increased complexity tended to detract from the central message.

The skewed distribution of disease cost, further emphasises the importance of using decision analysis techniques in this context. The clients attitude to risk is particularly important. As farmers are reputed to be risk averse (Boehlje & Eidman, 1984), they are likely to favour preventive approaches to animal health control in order to reduce the chance of an extremely severe outbreak. The non-pecuniary consequences of such an outbreak, such as reduced animal welfare and increased stress for their carers lends weight to this argument. At the extreme, outbreaks reported in this survey showed such high costs that the viability of the whole farm business might be threatened. Informal feedback from the practices involved suggest that this was indeed the case. An important part of the talks was therefore to explain the significance of the skewed distribution of disease cost for the management of farm animal health and welfare.

Presentation of the components of disease cost gives further valuable information to the farm manager. Few appreciate the considerable opportunity cost of their time and capital devoted to an outbreak of pneumonia and in particular to enteritis. The authors feel that the figures reported here are probably an underestimate, the opportunity cost of farm labour being fixed at £1/hour to reflect the widespread use of family labour for these tasks.

More generally, the components of disease cost provide an indication as to where priorities should lie if disease costs are to be reduced. Certainly drug costs and veterinary charges are important but they do not represent the full extent of the costs. If farmers measure the extent of disease problems by the size of the veterinary and medicine charges then this is certainly a gross under estimate that may lead to undue complacency and hence failure to invest in worthwhile disease prevention strategies.

Clearly, this educational approach to animal health control was well received both by farmers and veterinarians. There is however a problem conveying the economic information in a way that ensures appropriate action in the individual case. There are conflicts providing the appropriate balance between generality and specificity and between understanding and complexity. These difficulties will only be resolved if farmers and veterinarians take on the ethos of this approach together in partnership on a regular basis.

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ELICITING EXPERT OPINIONS ON RISK FACTORS CONCERNING INTRODUCTION OF VIRUS: APPLICATION OF CONJOINT ANALYSIS

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The export of meat represents a major part of the income earned by the Dutch livestock industry. In 1994, the meat export had a value of more than 4.5 billion US dollar (PVE, 1995). Outbreaks of contagious animal diseases may cause export bans and are therefore greatly feared in the Netherlands and other meat exporting countries. Hence, adequate disease prevention and eradication is of major interest of both government and private industry. To help maximizing the efficacy of existing programs and evaluating beforehand the consequences of possible alternatives, computer simulation is considered to be a valuable approach. Such a modelling approach should provide more insight into the risk and economic consequences of virus introduction into the country (Dijkhuizen, 1992).

It would be ideal to base such a model upon historical and experimental data. But especially quantitative information concerning the introduction of virus into the Netherlands (and other countries) is lacking. Table 1 gives an overview of the outbreaks in the Netherlands of six of the most important diseases, which are: Foot and Mouth Disease (FMD), Classical Swine fever (CSF), African Swine Fever (ASF), Swine Vesicular Disease (SVD), Newcastle Disease (ND) and Avian Influenza (AI). According to this table, CSF caused by far the largest number of outbreaks in the last 13 years, followed by ND. The number of outbreaks caused by FMD and SVD is relatively small. AI, so far, has never been recorded in the Netherlands, the nearest outbreak of this disease has been recorded in Ireland, in 1989.

Table 1 shows that outbreaks of these diseases occur irregularly in time and magnitude, making it very difficult to derive general properties and predictive values. Furthermore, the Netherlands ceased preventive vaccination for CSF in 1986, and for FMD in 1991. In 1992, the European Union decided to cease preventive vaccination for all list A diseases, except ND (vaccination for ND was and is compulsory in the Netherlands). Thus, some of the outbreaks presented in Table 1 occurred in a vaccinated and more or less protected population, while, for all diseases except ND, the Netherlands is now dealing with an unvaccinated and thus highly susceptible livestock population. This will influence the epidemiology and economics of outbreaks and the effectiveness of prevention and eradication strategies. Moreover, the recent developments in the eastern part of Europe has resulted in a number of countries becoming more intensive trading partners to the countries of the European Union. Information on the animal health situation in these countries is (still) scarce, making them an uncertain factor.

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Table 1. Number of outbreaks in the Netherlands 1983-1992 (MLNV, 1983-1992).

Year	FMD	CSF	ASF	SVD	ND	AI
1983	4	161				
1984	2	176				
1985		36				
1986		1	2			
1987		1				
1988						
1989						
1990		2				
1991					1	
1992		7		6	39	
1993					22	
1994				4	15	
1995						
Total	6	384	2	10	77	0

Experimental data are also scarce. Many researchers, including Terpstra (1987, CSF), Mann and Sellers (1989, FMD) and Becker (1987, ASF), have done work in this area, but most of their findings are qualitative only.

Despite this lack of information, decisions concerning eradication and prevention programs must be, and are made anyway.

The study reported in this paper describes a computerized questionnaire experiment aimed at the elicitation of subjective knowledge of people involved in disease prevention and eradication. The questionnaire was based on the so-called 'Conjoint Analysis' technique (Cattin and Wittink, 1982). Main subject was to derive information for use in the simulation model mentioned above. Besides, it was also interesting to explore possible differences in view between experts originating from different backgrounds.

This paper summarizes how the experiment was designed and how conjoint analysis works. Also a selection of results is given. Further evaluation of the data is still in progress.

EXPERIMENTAL DESIGN

Three evening filling workshops were organized for which a total of 50 people was invited. This group includes almost all people (in the Netherlands) thought to be knowledgeable about, or even expert on, either one of the six diseases under study. To study the possible influence of the participants' background, three groups were made: 'policy' (ministry of agriculture, animal health service), 'research' (university, research institutes), and 'field' (active during outbreaks).

The whole questionnaire was computerized and designed to be self-explanatory. In this way, the participants were able to complete the task with a minimum of interaction with either the other participants or the organizers. The participants were given the opportunity to choose the disease on which they thought themselves to be most knowledgeable. Questions were asked for this disease only.

CONJOINT ANALYSIS

Background

Conjoint analysis has been used extensively in marketing research to elicit the subjective views and preferences of consumers (Cattin and Wittink, 1982). Research of Horst et al. (1995) showed the potential value of the technique for the elicitation of risk factors concerning contagious animal diseases.

Basic assumptions of the conjoint technique are: (1) a product can be described according to levels of a set of attributes, and (2) the person's overall judgement with respect to that product is based on these attribute levels (Steenkamp, 1987). For example when selecting a car, important attributes in deciding what kind of car to buy are: colour, price, make, maximum speed, size, etc. Conjoint analysis is a technique that enables the quantification of the relative importance of these attributes. It was developed in the 1960s (Krantz, 1964; Luce and Tukey, 1964; Krantz and Tversky, 1971) and was rooted in traditional experimentation techniques.

Conjoint analysis is a so-called 'decompositional method'. Respondents are asked to give their opinion on a 'complete' situation. The researcher later on uses statistical techniques to decompose the situation into parts and derive the respondent's opinion concerning these parts. The car-selecting problem provides a good example of a typical conjoint experiment. In this case, a respondent will be shown a number of small cards, each presenting a different car. On those cards, the car is described as a combination of the attributes (speed, make, etc.), called a profile. The respondent is asked to give a score or a rank for each profile (each card). Using statistical analysis, the importance of the individual attributes can be estimated afterwards. These 'importancies' are termed 'part-worth scores' and indicate the influence of each attribute on the respondent's preference for a particular profile (in this case, a particular car). The car industry could use this information about part-worth scores, for example to predict the 'likelihood of buying' when a new car is developed.

Conjoint analysis may look like a rather complicated and indirect method to reveal systematic components that underlie people's evaluations of objects. On first sight, a compositional method, such as direct questioning, may seem to be a more attractive option. Compositional methods ask respondents to assess values for attribute levels, and use these values to build up preferences for attribute bundles or profiles (Huber, 1974). These methods have speed and simplicity as main advantages and are also referred to as self-explicated methods. However, there are also some problems, the major one being lack of realism. It is difficult for respondents to provide a non-biased score for one particular attribute, holding all else equal. Heavy biases may result from direct questioning on the importance of socially sensitive factors (Green and Srinivasan, 1990). The decompositional conjoint method provides a more realistic situation to the respondent because attributes are evaluated as combinations (as is the case in the 'real world'). Besides, according to Davis and Olson (1985) lack of understanding statistical analysis can heavily bias direct questions on probabilities. In these cases a more indirect approach is preferable. Many researchers have compared the predictive performance of the conjoint method with the self-explicated approach and in most studies the conjoint techniques outperform the latter one (Green et al. 1983; Huber et al., 1993). An advantage of conjoint analysis when working with expert panels is that the techniques provides information on the consistency of the answers given by the participant, which gives insight into the reliability of the results.

Conjoint analysis provides a useful tool to quantify feelings or subjective knowledge in all cases where an object or event and its related attributes can be determined. The method is relatively new to the field of animal health economics but a first experiment concerning risk factors on contagious diseases, done during the 7th International Symposium on Veterinary Epidemiology and Economics in Kenya, August 1994, showed promising results (Horst et al., 1995). In this experiment the risk factors were seen as the attributes, together forming the event 'virus introduction'. The results and experiences of this Kenya experiment have guided and framed the use of conjoint analysis in the current (computerized) questionnaire.

Use in the experiment

Transport of virus from any country into the Netherlands is caused by the so-called 'risk factors'. Literature and earlier in-depth interviews with experts produced a list of risk factors for each of the six diseases under study. For example for FMD and CSF, the following factors were taken into account:
- import of livestock
- import of animal products
- feeding of import swill (airports, harbours)
- tourists
- returning livestock trucks
- wildlife
- air currents (airborne transmission)

The conjoint analysis, as described in the previous paragraph, was used to derive the relative importance of each of these risk factors. The introduction of virus into the Netherlands was seen as the 'event', the risk factors were the 'attributes'. Each factor could be either present or not present (two levels) which made a total of 2^7 or 128 possible profiles. Using all profiles (a complete factorial design) would be impractical. However, the number of profiles can be reduced by using a fractional factorial design, with only a minimal loss of accuracy. The basic plans of Addelman (1962) were used to construct the necessary orthogonal fractional design for this study, which resulted in eight profiles. Three randomly chosen profiles were added as 'holdouts', which were used to check the fit of the model when analysing the results of the conjoint analysis (regression coefficients are based on the first eight profiles only). These holdouts could also be used to gauge the respondent's consistency in answering the questions.

Instead of cards (as described in the car-example), the participants of the workshop analysed the profiles on the computer screen. The computer presented only one profile at a time which consisted of all risk factors with for every factor the remark 'present' or 'not present'. The participants were asked to imagine the situation presented on the screen as being the current situation in the Netherlands and to give a risk score (a number between 0 and 100).

The results were analysed using SPSS (SPSS Inc., Chicago), a statistical package that includes a special option for handling conjoint analysis (using regression techniques). The customary approach to conjoint analysis is disaggregate. That is, each respondent is modelled separately and the fit of the model is examined for each individual respondent (Hair et al., 1990). The following model was used:

$$\text{score} = c + \beta_1 * x_1 + \ldots\ldots + \beta_7 * x_7$$

In this simple additive model, **score** is the risk score given by the respondent, **c** is a constant, the **β**'s are the estimated coefficients belonging to the risk factors, and the **x**'s are the risk factors (with values 1 = present or 0 = not present). Based on the model, the method estimates the relative importance of each risk factor (all factors together add up to 100%).

ADDITIONAL QUESTIONS

The elicitation of the relative importance of the risk factors formed the major part of the questionnaire. Besides, some additional questions were asked about country clusters and high risk period.

Country clusters

The Netherlands interact with almost all countries of Europe, thus in principle all countries could be responsible for transfer of virus into the Netherlands (assuming that an outbreak occurs in one of these countries). To incorporate country differences while keeping the whole exercise of controllable size, the countries were clustered into the following five groups:

cluster 1: Belgium, Germany, Luxemburg
cluster 2: Greece, Italy, Portugal, Spain
cluster 3: Austria, France, Switzerland
cluster 4: former eastern Europe
cluster 5: Great Britain, Ireland, Scandinavia

High Risk Period

The High Risk Period (HRP) defines the period in which the virus can spread freely. The length of this period is one of the most important parameters determining the magnitude of an outbreak. The HRP starts when the first animal is infected and ends when all eradication measures are fully into operation, i.e. the region under consideration does not contain any risk for other countries anymore (eradication of the virus and/or establishing of waterproof export controls/export bans). The HRP can be divided into two periods:

HRP1: starts when the first animal is infected, and ends when the first animal is detected.
HRP2: starts with the first detection, and ends when all measures are effective.

The length of HRP1 depends on the alertness and motivation of farmers and veterinarians. The length of HRP2 depends on the efficacy of the animal health system of the country in which the outbreak occurs. The participants were asked to give a three-point estimation for the expected length of both HRP's (minimum, most likely and maximum expected length). This estimation was asked twice, for low and high virulent virus respectively.

RESULTS

A total of 43 people joined either one of the workshops, resulting in a response rate of 86%. In this paragraph, some general results of the workshops are shown. Disease-specific results are only shown for CSF and FMD. Further evaluations are underway and more detailed results will be available in later publications.

Risk factors

Table 2 presents the results of the conjoint analysis for CSF. This table shows the relative importance of the risk factors, for all country clusters. These results are obtained through regression analysis and based on the answers of consistent participants only (around 80%). Risk factors 'wildlife' and 'air' are only considered for cluster 1 (surrounding countries of the Netherlands).

Table 2. Relative importance of risk factors concerning introduction of CSF

Risk factors	Clusters 1	2	3	4	5
Livestock	56.0	55.6	58.4	60.3	59.4
Animal products	8.1	7.9	9.1	8.6	6.2
Swill	13.2	17.4	14.5	13.2	15.7
Tourists	4.4	3.6	3.3	4.8	5.9
Returning trucks	10.9	15.5	14.7	13.1	12.8
Wildlife	3.7	----	----	----	----
Air	3.7	----	----	----	----
Total	100.0	100.0	100.0	100.0	100.0

According to table 2, the differences between clusters are small. Import of livestock, swill and returning trucks are evaluated as the major risk factors for all clusters. Table 3 shows the relative importance of risk factors concerning FMD.

Table 3. Relative importance of risk factors concerning introduction of FMD

Risk factors	Clusters 1	2	3	4	5
Livestock	41.7	49.3	52.0	48.5	46.1
Animal products	12.9	6.9	4.7	8.4	15.6
Swill	9.3	12.1	6.6	4.1	8.0
Tourists	4.3	9.1	10.8	10.2	4.8
Returning trucks	15.0	22.6	25.9	28.8	25.5
Wildlife	7.1	----	----	----	----
Air	9.7	----	----	----	----
Total	100.0	100.0	100.0	100.0	100.0

Also for FMD, import of livestock is considered to be the most important risk factor for all clusters. Returning livestock trucks now ranks secondly, and tourists are considered more important than with CSF, especially for clusters 3 (Austria, France, Switzerland) and 4 (former eastern Europe).

To enhance the insight into the possible differences in view between the groups of participants, table 4 shows some more detailed results. This table also enables comparison between CSF and FMD in this respect. The results are shown for cluster 4 (former eastern Europe), one of the most 'risky' clusters according to the participants. Risks factors wildlife and air were only considered for cluster 1 (countries surrounding the Netherlands) and are therefore not mentioned in this table.

Table 4. Relative importance of risk factors, CSF, cluster 4, per background .
(1 = policy, 2 = research, 3 = field)

	CSF			FMD		
Risk factors	1	2	3	1	2	3
Livestock	62.2	74.7	57.0	62.2	36.1	44.8
Animal Products	8.5	8.2	8.3	4.5	5.9	9.1
Swill	11.6	12.0	14.4	2.3	12.3	6.3
Tourists	2.8	1.9	6.1	4.9	17.8	12.4
Returning trucks	14.9	3.2	14.2	26.1[a]	27.9[a]	27.4[a]
Total	100.0	100.0	100.0	100.0	100.0	100.0

[a]Lower than the value in table 3 due to scaling effects

For both diseases, import of livestock is thought to be the most important factor according to all groups. All CSF-groups consider swill to be the second most important factor concerning the introduction of CSF virus from cluster 4 into the Netherlands. Evaluating CSF, the main difference between the groups concerns the risk factor returning trucks. According to both 'policy' and 'field', this is an important factor (third in the ranking). According to 'research' the factor is of minor importance. The FMD results show more differences between groups. 'Research' is less extreme (differences between risk factors are smaller) in its opinion than both 'policy' and 'field'.

High Risk Period

Table 5 presents the HRP1 concerning CSF. The results are given for all country clusters and for the Netherlands. According to this table, all groups indicated that the countries of cluster 4 (former eastern Europe) have the highest HRP1. Also cluster 2 (Spain, Portugal, Italy and Greece) turned out to have a high HRP1. The value for the Netherlands is much lower. Group 'policy' was more optimistic about the length of the HRP1 than 'research' and 'field'.

Table 5. HRP1 (days) for virulent virus

	Cluster 1	2	3	4	5	NL
Total	27.5	37.9	25.1	43.1	23.7	23.1
Policy	22.5	27.2	20.8	36.1	22.4	18.1
Research	29.3	48.0	29.3	54.0	29.0	28.4
Field	29.5	36.8	23.1	37.5	17.9	25.3

Table 6 considers the results for HRP2. The general trend in this table is very comparable to the trend in table 5. Again the highest estimates are for clusters 4 and 2. Also here 'policy' estimates lower values than 'research' and 'field', though the differences seem more extreme here than for HRP1. The HRP2 results show the same trend as those of the HRP1. Main difference is that most estimates are lower for HRP2 than for HRP1.

Table 6. HRP2 (days) for low virulent virus

	Cluster 1	2	3	4	5	NL
Total	8.1	22.6	17.8	26.0	15.9	13.8
Policy	5.2	13.3	9.7	20.9	3.8	4.1
Research	31.3	42.0	31.0	43.7	21.5	14.7
Field	23.6	33.2	28.3	35.0	22.2	17.8

The estimates for FMD (not shown here) follow a similar trend but are somewhat lower.

FINAL REMARKS

The results show that policy makers seem to be more optimistic about the alertness of farmers and veterinarians and the efficacy of the Dutch eradication system (i.e. they estimate lower values for the HRP) than researchers and people working in the field. Considering the importance of risk factors, the differences between the groups are small. Further analysis should provide enhanced insight into the consistency of the participants. Low consistency could indicate a lower level of knowledge, so consistency may be used to weight the results. A check on the validity of the method and the reliability of the results will be performed by comparison with historical and experimental data, if available.

The differences in view between the different background groups may have implications for the efficacy of eradication and prevention programs. Group discussion with a selected group of participants and others involved in disease eradication and prevention will be used to obtain more insight into the underlying reasons for these differences.

The 'Gold Standard', i.e. the true value, of the risk factors is impossible to obtain. However, although the scientific analysis is not complete yet, the results so far provide interesting information about the opinions of people involved in the area of disease control, originating from different backgrounds, on aspects of outbreaks of contagious animal diseases in the Netherlands. It could be concluded that methods such as conjoint analysis, are very useful in quantifying the subjective views of experts about these aspects. Until historical data and/or experimental research are able to provide better results, the outcome of these methods, incorporated in research as described in this paper, will be valuable information to be used in modelling risks and economic consequences of outbreaks of contagious animal diseases. The results of this study will be used as input data for the simulation model described in the introduction.

Sensitivity analysis will be used to study the consequences of different views and different strategies. Because a considerable part of the input of the model will be based on estimates and assumptions, sensitivity analysis may also play a major role in evaluating the importance of the uncertain data. In this way the analysis can be used to guide further (experimental) research aimed at improving the input and thus improving the reliability of the outcome of the model.

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RISK AND INFORMATION

IMPROVING THE RISK ASSESSMENT IN VETERINARY EPIDEMIOLOGICAL STUDIES: CRYPTOSPORIDIOSIS IN CATTLE AND LEPTOSPIROSIS IN HORSES

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One of the most perplexing problems facing epidemiologists is to accurately assess and quantify the relation between risk factors and disease. In veterinary investigations, epidemiologists often collect data from groups of animals and perform the analysis using logistic regression to identify factors significantly associated with the risk of the disease under investigation. Because of the limited resources and imperfect knowledge, data are collected on a limited number of potential factors while the rest are assumed to be randomly distributed among these groups. Unfortunately, under these circumstances, the assumption of independent and identically distributed observations is violated because animals managed under similar circumstances tend to be affected similarly with the risk factors in relation to their likelihood of developing a disease. Consequently, the traditional analytical techniques such as logistic regression are unsuitable for hypothesis testing because the variance estimate for the parameters of interest in these techniques tends to be smaller. Mixed effect models might be more suitable for evaluating the significance of these hypothesized factors in relation to disease than traditional (ordinary) models, ie, logistic regression model (OLR). We hypothesized that this might be the case in two separate epidemiological investigations which we carried out to identify factors associated with two different diseases. In each of these investigations, data on putative risk factors were collected from group of animals.

The diseases under investigation were cryptosporidiosis in dairy cattle, and leptospirosis in horses. The first data set, (cryptosporidiosis in cattle) was collected in a cross-sectional study aimed towards identifying factors associated with the risk of infection with this organism in dairy herds in a watershed in New York State. The second investigation was also a cross-sectional study designed to identify factors associated with the likelihood of seroconversion to leptospirosis among horses in New York State. Samples were collected from both study populations and the disease status was determined. Data on putative risk factors for each disease were collected by personal interview and analyzed using OLR. Later, mixed effect logistic regression (MELR) models were used to test for the presence of intragroup correlation (extra-binomial variation) in each of the data sets in relation to the disease under investigation. For each data set, we also compared the results obtained from fitting the three different MELR models to determine which model best described the relationship between the respective disease and its risk factors. The comparisons were made by examining the goodness of fit for each model.

We found that there were evidence of intragroup correlation in both data sets and that correlation had affected the inferences made on some of putative risk factors. *Cryptosporidiosis parvum* data was fitted best by the betabinomial MELR model, while the logistic binomial was the best fit for the *L bratislava* data. The intragroup correlation varied from 0.59 in the *C parvum* data to 0.18 in the *L bratislava* data.

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INTRODUCTION

The goal of epidemiological studies is to identify risk factors that contribute to the likelihood of a specific disease. In the process, epidemiologists collect data on these putative risk factors and test hypotheses of possible association with the disease under investigation. It is generally accepted that efforts are made by investigators to minimize the effect of selection and measurement biases while multivariate statistical analysis approaches are employed to control for confounding and effect modification (Kleinbaum et al., 1982). One of the commonly used statistical technique for risk identification and quantification in binary outcome (disease) is the ordinary logistic regression (OLR) model (Hosmer and Lemeshow, 1989).

The use of epidemiological data to generate a hypothesis with regard to causation or etiology is not a self-evident process. It is derived from a basic premise, or axiom, that disease does not occur randomly, but in patterns that reflect the operation of underlying causes. Because knowledge is not perfect and resources are limited, it is likely that epidemiologists will not be able to identify all potential risk factors that would explain the variation in the occurrence of the disease. When all these factors are considered in the OLR model, the unexplained variation may be in excess to what can be attributed to sampling variations (Williams, 1982, Rosner, 1982). To overcome this problem, investigators would either collect more information on other factors which may associate with the disease or assume a source of extra-binomial random variation between observations. It is not unreasonable to accept the assumption of a potential source of extra-binomial random effect (Pierce and Sands, 1975; Hasemand and Kupper, 1979; William 1982).

In veterinary medicine, diseases are generally studied on cluster of populations and the data on the risk factors are often collected from groups of animals, e.g., herd or stables, and analyzed using the logistic regression (Klienbaum, et al., 1982; Hosmer and Lemeshow 1989) . The purpose of the analysis is to identify factors that are significantly associated with the observed disease. In using these methods, researchers assume independence between animals with respect to disease status in the study population. This assumption is often violated when studies are conducted on a population comprised of multiple groups (herd or stable) since animals within each group tend not to be similar but different from other groups. For example, the likelihood of a calf becoming infected with *C parvum* is influenced by the presence of this parasite in other calves on the same farm since infection occurs by ingesting the infection stage from the environment. It is more likely that calves from the same farm would have a similar risk of infection, by virtue of the way they are managed and the dynamic of the disease within a closed population, than would calves that were raised on different farms. It is not unreasonable to assume that calves in a herd are at similar risk of contracting *C parvum* and this risk is likely to be different from the risk of other herds.

This similarity with respect to the risk of disease between the member of the same herds or the same stable violate the assumption that the study units are independent and identically distributed (*iid*) which is required for statistical tests (Pierce and Sands, 1975). One way to overcome this violation in performing hypothesis testing, is to change the study unit from an individual calf or horse to herd or stable. This reduces the number of study units in the analysis and therefore, the measure of dispersion (variance) will be larger than if the individual observations were used as unit of study. Ignoring the fact that these data are collected on correlated observations and uses the traditional or fixed effect models to identify risk factors significantly associated with the likelihood of a disease leads to information bias. The information bias results from a measurement error which is the underestimation of the variance of the parameter of interest. The variance will be smaller, and therefore, may lead to false statistical inferences, ie, large z values in the Wald's test.

Alternative statistical models have been proposed in the literature to handle under or over-dispersion that occurs in correlated data with a binary outcome, ie, disease no disease (Haseman and Kupper, 1979). These models can accommodate both the fixed effect and random effect component, and are generally referred to as mixed effect logistic regression models (MELR) (Stiratelli et al., 1984; Searle et al., 1992; Zeger et al., 1988). The choice between the random and fixed effect models depends on how the individual effects are assumed to operate, ie, are independent from the group effect or not.

The objectives of this study were to examine whether the use of the mixed effects logistic regression model improves the risk assessment for *C parvum* infections in dairy cattle and *Leptospira interrogans* infection in horses; to quantify the intragroup correlation, in these study populations; and to evaluate the suitability of different MELR models for specific data.

MATERIAL AND METHODS

Cryptosporidium data

Data were collected in a cross-sectional study to identify factors associated with the likelihood of infection with *C parvum* among dairy cattle in the watershed in New York State. A random sample of 99 dairy herds constituted the study population. A complete description of the target population, study population, and the recruitment methods is given elsewhere (Wade et al., 1996). Fecal samples were collected rectally from the animals using a stratified sampling plan: all calves under 6 months of age were sampled; calves in the age group between 6 to 24 month; and nine cows from the animals 24 months or older. This sampling design was adopted because the literature indicated that calves below 6 months of age are most at risk of infection. Farms were sampled once from June 29, 1993 to June 9, 1994.

Laboratory analysis of the fecal samples was conducted using standard quantitative centrifugation concentration flotation (zinc sulfate, and sugar) techniques (Georgi and Georgi). Samples from calves under one month of age were cleaned using a Tween 40 detergent procedure before adding flotation medium. Microscopic examination was done using bright field and phase contrast microscopy.

Data on potential risk factors that were hypothesized to be associated with the likelihood of infection with *C parvum* were collected by personal interview of the farm owner or manager. Table 1 shows a listing and description of the putative risk factors.

Equine leptospirosis data

The study population was selected from the 39,000 equine operations in the 1988 New York State Equine Census (New York Agricultural Statistics Service). Description of the target and study populations are provided elsewhere (Barwick et al., 1996a). A total of 2,967 horses from 572 equine operations were sampled. These equine operations were visited to collect blood samples. During the farm visit a questionnaire was administered to collect geographic, demographic, management, and health information on the study population. Blood samples were collected into sterile vacutainers or tubes and stored on ice while transported to the New York State Diagnostic Laboratory, Cornell University for processing. Sera were separated and stored at -70° C until tested using the microscopic agglutination test (MAT) for seropositivity to the *Leptospira interrogans* serovar, *L. bratislava.* All sera reacting to a dilution of ≥ 1:100 were considered positive.

Hypothesized risk factors were grouped into four indices of possible sources of exposure to *L. bratislava*. Complete description of the risk constituents of the indices is reported by Barwick et al., (1996b). These indices were: rodent exposure index, soil and water index, wildlife exposure index, and management index. The first index included those factors which were perceived to play a role in the exposure of a horse to *L. bratislava* in its domestic environment. The second index included those factors related to wildlife as a potential source of exposure to *L. bratislava*. The factors in this index indicate the horse would be exposed to in its outdoor environment. The third index, contained risk factors that were perceived to put the horse at risk via exposure to soil and water. These include: distance the horse resides from ponds, swamps, and creeks; the size of any bodies of water; pasture type; paddock type; and elevation. The fourth index included management practices directly affecting the horses' exposure to *L. interrogans*, such as the frequency and type of worming medication used, whether or not if and how fly spray was used, and how the horse was used (trail riding, competition, retired).

Description of procedures for development of the indices were reported earlier (Barwick et al., 1996b). First, normal logistic regression analysis was used to identify, within each index, factors that were significantly associated with the likelihood of seropositivity to *L. interrogans* using the BMDP statistical package. Secondly, a weighted index for each of the four groups (indices) was generated by assigning a weight equal to the sum of the regression coefficients of the significant factors included in the index.

<u>Statistical analysis</u>

Ordinary logistic regression analysis was used to identify risk factors significantly associated with the likelihood of each disease in the two data sets. The purpose was to identify factors significantly associated with the disease while simultaneously controlling for the effect of other factors. The analysis was performed using backward stepping procedure in BMDP (Dixon et al,

$$P(D_i / Z_j) = \frac{1}{(1 + \exp^{-(\alpha_i \quad \Sigma\beta_j Z_j)})}$$

1992). The models was specified as follows:
where $P(D_i/Z_j)$ is the probability of the disease (*C. parvum* infection or *L. bratislava*); α the likelihood of a study unit to develop the respective disease under standard circumstances ;β_j is the changes in the likelihood of the disease due to the presence of the matrix of risk factors Z_js.

A random-effects assumption was added to the previous model by adding a non-negative parameter, σ_K, to test the hypothesis that the inter group variation is relatively small relative to that between groups (herds or stables). The MELR model was specified as follows:

$$P(D_i / Z_j \varepsilon_K) = \frac{1}{(1 + \exp^{-(\alpha_i \quad \Sigma\beta_j Z_j \quad \varepsilon_K \sigma)})}$$

where $P(D_i/Z_j, \varepsilon_K)$ is the probability of the disease for a study unit *i* located within the group level κ and has a parameter σ. The statistical significance of this parameter was evaluated by comparing the square root of the likelihood ratio statistic of the parameter with the one-tailed normal distribution because $\sigma \geq 0$. The analysis of the MELR model was achieved using EGRET statistical software (1990).

If the random effect was significant, the correlation within groups (ρ) was estimated for each disease and each risk factor. The ρ was estimated from the MELR on the logit scale as follows:

$$\rho = \frac{\sigma^2_{RE}}{\sigma^2_{RE} + \sigma^2_{SL}}$$

where σ^2_{RE} was the variance of the random effect estimated from the MELR model and equal to σ^2. The σ^2_{SL} was the fixed variance for the standard logistic regression model and estimated as

$$\sigma^2_{SL} = \frac{\pi^2}{3} \approx 3.3$$

suggested by Searle et al (1992) as follows:
ρ is interpreted as the proportion of variability in the risk of the disease that is due to the variability between members of the same herd or stable.

For each data set, we compared the results obtained from fitting three different mixed models: the betabinomial which is based on the beta distribution; the logistic normal which is based on the standard normal distribution; and the logistic binomial distribution which is based on the binomial distribution. The purpose was to determine which model best describe the relation between the hypothesized factors and the risk of respective disease. The comparisons were made by examining the goodness of fit for each model.

RESULTS

Cryptosporidium data: Twenty percent of the 99 herds used in this study had at least one animal infected with *C parvum*. Out of the 14 factors that were hypothesized to be associated with the likelihood of infection with *C parvum*, 7 were significant (Table 1). The risk of infection with *C parvum* increased due to lack of cleaning the calf raising area, number of calves, changes in farm size, and to using water sources other than wells. The risk of infection with *C parvum* decreased with the implementation of preventive measures at calving.

There was a significant excess variation among cows with respect to the risk of *C parvum* as determined by fitting the betabinomial logistic regression. The results of the analysis are shown in Table 2. There was a significant heterogeneity among the study population in four of the risk factors and the likelihood of infection with *Cryptosporidium*. These factors were: change in the farm size in the last 5 years, water sources for cows, water sources for calves and preventive measures at birth. Estimates of the standard errors obtained for these risk factors in the OLR model and the assumption of independence and identical distribution were incorrect and biased. The standard errors for those risk factors increased by a range of 2 to 4 times in spite of the fact that estimate of the effect parameters stayed the same (Table 2).

Neither the logistic-binomial or the logistic normal models fitted the *Cryptosporidium* data.

Table 1. Factors associated with *C parvum* as identified with the ordinary logistic regression

Variable	Regression coefficient	Standard error	P-value	Odds ratio (95% Confidence interval)
Cleaning of calf area				
Washed	0.0			1.0
Not washed	1.424	0.307	<0.001	4.2 (2.2 - 7.6)
Number of heifers	0.105	0.014	<0.001	NA
Frequency of bedding change				
Daily	0.0			
Less frequent	1.679	0.313	<0.001	5.4 (2.9 - 9.9)
Change in farm size last 5 years				
No change	0.0			1.0
Change	1.348	0.319	<0.001	3.9 (2.1 - 7.2)
Water source for cows				
Wells	0.0			1.0
Not wells	1.168	0.350	<0.001	3.2 (1.6 - 6.4)
Water source for calves				
Other	0.0			
Wells	- 2.493	0.446	<0.001	1.0
Preventive measure at birth				
No	0.0			1.0
Yes	0.779	0.332	0.019	2.2 (1.1 - 4.2)
Constant	-10.941	0.883		

Table 2. Factors associated with *C parvum* as identified with the Beta-Binomial logistic regression

Variable	Regression coefficient	Standard error	P-value	Odds ratio (95% Confidence interval)	Intra-group correlation
Constant (OLR)	-10.680	1.850			
Scaler (MELR)	0.063	0.030			0.24
Cleaning of calf area					
Washed	0.0			1.0	
Not washed	1.881	0.732	0.010	6.6 (1.6 - 27.5)	0.23
Number of heifers	0.105	0.037	0.005	NA	0.21
Frequency of bedding change					
Daily	0.0			1.0	
Less frequent	1.475	0.66	0.025	4.3 (1.2-15.9)	0.18
Change in farm size last					
No change	0.0			1.0	
Change	1.131	0.680	0.096	3.1 (0.8-11.7)	0.16
Water source for cows					
Wells	0.0			1.0	
Not wells	0.083	1.560	0.996	0.1 (0.01 - 21.2)	0.12
Water source for calves					
Other	0.0			1	
Wells	-1.170	1.600	0.464	0.01 - 7.1	0.12
Preventive measure at birth	0.0			1.0	
No	0.532	0.66	0.42	1.7 (0.5 - 6.2)	0.12
Yes					

Leptospira data set: Only seven factors were found to be significantly associated with the likelihood of seroconversion to *L bratislava* of all 18 hypothesized factors. These factors, which were identified by the OLR model are listed in Table 3. The likelihood of seroconversion to *L bratislava* was increased by the hours a horse was in the stall, by the presence of a pond, the presence of cows on the farms, increased likelihood of exposure to rodents, and had management practices that increased the likelihood of seroconversion. The likelihood of seroconversion to *L bratislava* decreased with the good hygiene on the farm, and spending more hours in the pasture. There was a significant curvilinear relationship between the age of the horse, and the likelihood of seroconversion to *L bratislava*.

There was a significant intragroup (stables) correlation in the study population as was determined by the logistic binomial regression (Table 4). After adjusting for the intragroup correlation, three factors remained that were significantly associated with the likelihood of seroconversion. The standard errors for all of the risk factors that were found to be significantly associated with the likelihood of seroconversion to *L bratislava* in the OLR increased in the MELR model. However, the magnitudinal effect of all of these factors remained relatively the same. The standard error for farm hygiene, hours in pasture, presence of ponds, and cows on the farm increased to the extent that the association of these factors with the risk of seroconversion became non significant. The logistic binomial regression was the only model that was available in the statistical package that was used (Egret) for distinguishable data. The intragroup correlation varied from 0.18 to 0.11.

DISCUSSION

The objectives of this study were to examine the presence of extra-binomial variations in two data sets which were collected to investigate risk factors that were associated with each respective disease and to examine whether estimates obtained under the OLR are reliable. The study was motivated by the statistical literature in general, and veterinary epidemiology specifically, which indicated that over or under dispersion is common in data collected from groups of study units as a results of intragroup correlation (Mantel et al, 1969; McCullagh and Neder, 1989; Williams, 1982; Kristula et al., 1992 Atwill et al;, 1993; Correa et al 1993; Curtis et al., 1993). The impact of this intragroup correlation violates the basic assumption of independence and identically distributed (*iid*) observations that is required for the use of OLR.

Several investigators have proposed alternative approaches for OLR analysis in circumstances where intragroup correlation exists in the data. These alternatives revolved around using a family of MELR models (Pierce and Sands, 1975; Hasemen and Kupper, 1979) that allow for the handling of the intragroup correlations. The proposed MELR models that are used in data with binary outcome include: betabinomial logistic regression, logistic normal, and logistic binomial regression models. Each model has its own advantages and limitations.

The betabinomial regression model was the first to be suggested for the use in the analysis of correlated binary data to model extra-binomial variation (William, 1975; Crowder, 1978). This model is basically an extension of the logistic regression model where the probability of disease (event of interest, ie, success) is allowed to vary between groups in such a way that a multinomial distribution is generated rather than a single binomial distribution (Figure 1). The parameters for the beta distribution are estimated using the maximum likelihood method. The literature suggested that the betabinomial model does not always fit data sets well in comparison to the other proposed methods of analysis (Mauritsen, 1984).

Table 3. Risk factors associated with *L bratislava* as determined by the ordinary logistic regression

Factor	Regression coefficient	Standard error	P-value	Odds ratio	95% Confidence interval
Farm hygiene					
Not clean	0.0			1.0	
Clean	-0.252	0.149	0.10	0.8	0.6 - 1.0
Hours in pasture					
None	0.0			1.0	
Some time	-0.440	0.175	0.014	0.6	0.5 - 0.9
Hours in stall					
No stall	0.0			1.0	
Stall	0.835	0.239	0.001	2.3	1.4 - 3.7
Presence of ponds					
No pond	0.0			1.0	
Pond	0.177	0.098	0.070	1.2	1.0 - 1.5
Cows on farm					
No cows	0.0			1.0	
Yes	0.257	0.122	0.035	1.3	1.0 - 1.6
Rodent index	0.863	0.151	0.001	NA	
Management index	0.367	0.101	0.001	NA	
Age of the horse	0.142	0.020	0.001	NA	
Age2	-0.003	0.001	0.001	NA	
Constant	-1.409	0.213			

Table 4. Risk factors associated with *L bratislava* as determined by the logistic binomial regression

Factor	Regression coefficient	Standard error	P-value	Odds ratio	95% Confidence interval	Intra-group correlation
Constant	-1.364	0.254	0.001			
Random effect	0.632	0.086				0.18
Hygiene						
Not clean	0.0					
Clean	-0.245	0.186	0.187	0.8	0.5 - 1.1	0.18
Hours in pasture						
None	0.0			1.0		
Some time	-0.391	0.210	0.062	0.6	0.4 - 1.0	0.16
Hours in stall						
No stall	0.0			1.0		
Stall	0.651	0.293	0.027	1.9	1.0 - 3.4	0.17
Presence of ponds						
No pond	0.0			1.0		
Pond	0.129	0.126	0.306	1.2	0.9 - 1.5	0.18
Cows on farm						
No cows	0.0			1.0		
Yes	0.273	0.155	0.078	1.3	0.9 - 1.8	0.16
Rodent index	0.818	0.182	0.001	NA		0.14
Management index	0.367	0.119	0.001	NA		0.13
Age of the horse	0.146	0.022	0.001	NA		0.11
Age2	-0.003	0.001	0.001	NA		0.11

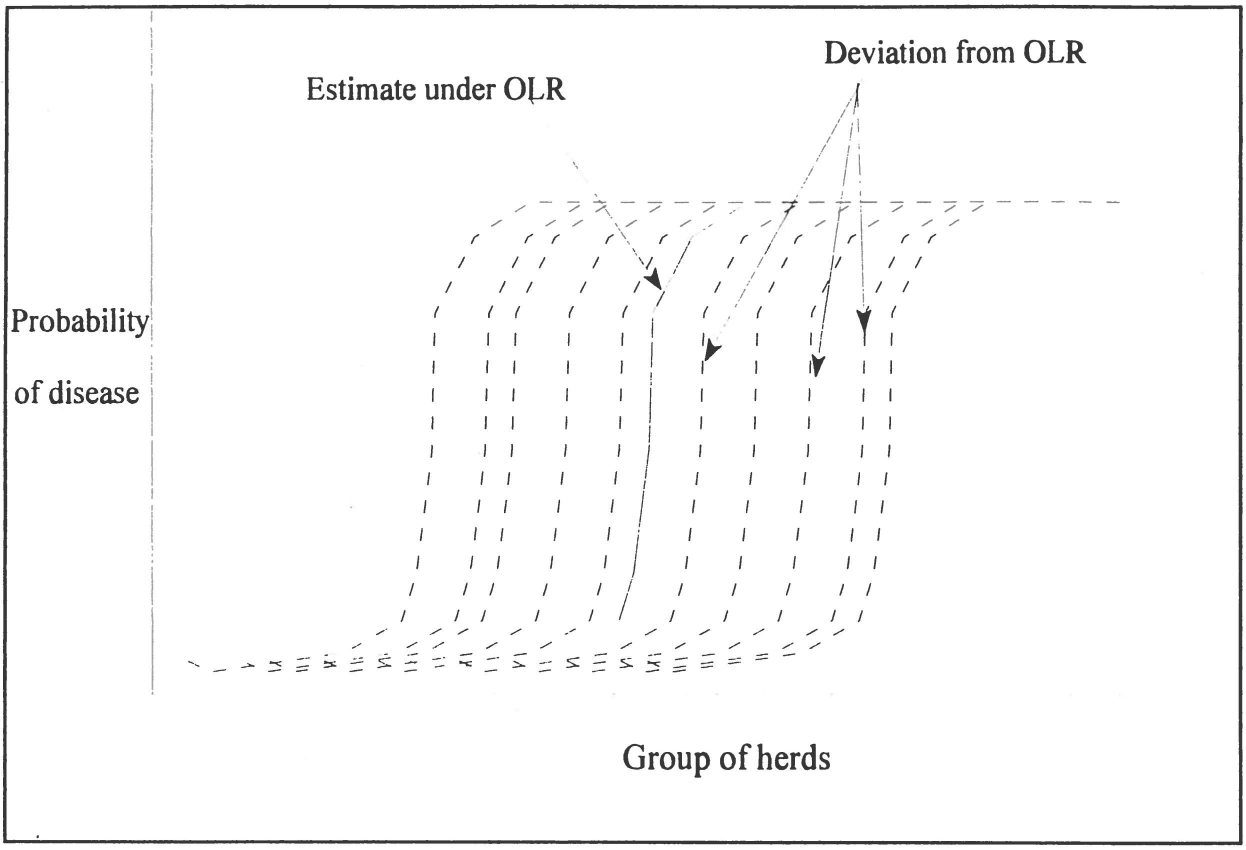

Fig. 1 Distribution of the multibinomial probabilities for herds with random effects

The logistic-normal regression which is an extension of the logistic regression model, was initially proposed by Pierce and Sands (1975). Although it is a relatively new technique, studies have suggested that the model is susceptible to great instability when the data used in the analysis are skewed (Spiegelman, 1988). There is evidence in the literature that the parameters estimated using a logistic-normal regression model are inaccurate when the within groups rates vary significantly and the group sizes are relatively large (Mauritsen 1984). We have encountered this problem when the *Cryptosporidium* data was analyzed using the logistic regression model. The effect parameters (regression coefficient) estimated in the betabinomial model are similar to those estimated using the ordinary logistic regression in comparison to the ones estimated using the logistic normal model (data not shown).

The logistic binomial regression model suggested by Mauritsen (1984) is an extension of the logistic regression analysis. The difference from logistic regression is that the random effects are assumed to be attached to the modelled probability of disease. In addition, the model assumes that there are a number of points in the selected prior distributions. This model is relatively new and relatively less common than the other two models.

The *Cryptosporidium* data is collated in the format of indistinguishable data, ie, the response variable represents a proportion of positive samples of all samples examined. In the indistinguishable data the putative risk factors, ie, covariate vector, are measured at the herd level and not at the single animal level. These data can be examined by the 3 types of MELR models, however, the betabinomial model was the only model that described the data best as determined by the goodness-of-fit test (William, 1975). Only the cleaning of the calf raising areas, the number of heifers on the farm at the time of sampling, and the frequency of bedding changes were significant after controlling for the intra-group correlation. The significance of the random effect parameter in the model is interpreted as evidence of presence of heterogeneity or extra-binomial variation in the data under the assumptions of the proposed model.

Conceptually, this can be interpreted that the individual herds are similar with respect to these factors, but they vary (or are dissimilar) from each other. If all of the herds in the watershed are similar with respect to the distribution of all potential risk factors which were not accounted for in the analysis, then the random effect parameter would not have been significant. Therefore, the error for the unmeasured variables in those herds are not randomly distributed, and there was need to identify other factors that were the source of variation among these herds. In other words, there are several factors which are particular for a specific herd or group of herds, and these factors modify the herd's risk of infection with *C parvum* to the extent that there is no more a single binomial distribution but a multinomial distribution in the study population (Figure 1). If it was possible to control for all of those factors that modify the risk in the population, then we would have accounted for the differences between herds, and detected no significant random effect in the data. However, we know that knowledge is not perfect and it is impossible to identify all factors that would contribute to the variability in the risk of infection among these herds. In these situations, investigators have the tendency to group the unmeasured risk factors in a "dumpster" called the random variation which assumes that these factors are randomly distributed in the study population.

One plausible interpretation to why factors that are significant in the OLR become non significant in the MELR model was that those variables are proxy for other unmeasurable variables that were assumed to be randomly distributed in the population. Therefore, when the effect of the unmeasured factors was controlled for by controlling for the random effect, those proxy variables become non significant. The significance of the presence of heterogeneity and extra-binomial variation, as determined by the significance of a random effect parameter, will lend credence to the explanation that there were other factors that were not accounted for in the risk analysis.

Another plausible explanation could be conceived through the accuracy of epidemiological studies. There are two main central issues in epidemiological studies concerning the accuracy of inferences drawn from them: validity and reliability (Kleinbahum et al, 1982). The validity refers to a systematic error in study units selection, data collection, and random variables measurement. Reliability refers to a random error in parameter estimation or inferences that are attributed mainly to either the sample size of the study population, or to the variation in the factors that were estimated, ie, the variance. If the extra-binomial variations exist, then this could be interpreted that within a herd or a stable, animals tend to be alike with respect to the risk. However, these animals are significantly different from those in other herds or stables. As a result, and after controlling for the random effect, the variance measured in OLR tended to underestimate the magnitude of the true variability between herds or stables with respect to that specific risk factor thus, biasing its significance of association with the disease.

The intragroup or intraclass correlation as measured in the logit scale is a useful parameter to compute because it provides an indication of the amount of variability in the risk of the disease that is attributed to the unmeasured variables (Rosner, 1982; Fleiss 1986; Atwill et al, 1995). The amount of intragroup correlation in the *Cryptosporidium* data is relatively small (24%) given the complex nature of *C parvum* infection in dairy herds, and the potentially large number of risk factors that might put animals at risk of becoming infected (Lengerich et al, 1993; Gerber et al., 1994). The cleaning of calf rasing area, frequent changing of bedding, and the number of heifers on the farm are the only 3 factors that remained significantly associated with increased risk of infection with *C parvum* after controlling for the extra-binomial variation among herds. These findings are consistent with some of the findings that were reported by Garber et al., (1994). The difference in the risk factors examined between the two studies suggests that there are other potentially important factors that have not controlled for. The continuing studies and the complete analysis of the data currently being collected should offer additional explanations.

The presence of intragroup correlation was also detected in the *Leptospira* data (Table 4). Four out of the nine variables that were found to be significantly associated with the likelihood of seroconversion in the OLR analysis were not significant in the MELR analysis. A similar explanation to the one offered in the *Cryptosporidium* data is applicable here. These 4 factors: farm hygiene, hours in pasture, presence of water body, and presence of cows on the farm might have been a proxy to other variables that were not accounted for in the OLR analysis. However, when the extra-binomial variability was adjusted for by using the MELR models, these factors become non significant. Lending credence to this speculation are the findings by Lee and Gale (1994) who identified several risk factors associated with the likelihood of seroconversion to *L bratislava* other than the ones evaluated in our study.

Barwick et al., (1996) attempted to improve the risk identification with regard to the likelihood of seroconversion to *L bratislava* by adopting the indexing system approach. The philosophy behind the use of the indexing system was that one can account for many risk factors in the analysis while avoiding the problem of multicollinearity (Mohammed 1990). In the MELR analysis carried out on this data, the rodent and management indices that were reported to be significantly associated with the risk of *L bratislava* (Barwick et al, 1996), remained significant. This can be interpreted that these indices play a major role in the risk of seroconversion, but there are other factors that should be considered in the future.

In conclusion, our study has demonstrated the importance of evaluating data for the presence of intragroup correlation, if the data are collected from clusters of animals or study units. Ignoring the presence of the intragroup correlation, will lead to information bias in epidemiological studies. This would be due to wrong inferences being made with regard to the significance of the effect of the investigated risk factors. Estimates of effects, and odds ratio, obtained in the OLR cannot be applied evenly across groups if intragroup correlations exist. The use of MELR models will no doubt allow for the correct assessment of the risk of the disease and ultimately the accurate estimate of risk.

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"I DON'T WANT TO BE TOLD WHAT TO DO BY A MATHEMATICAL FORMULA" - OVERCOMING ADVERSE PERCEPTIONS OF RISK ANALYSIS.

M.WOOLDRIDGE, R.CLIFTON-HADLEY, M.RICHARDS[1]

WHAT IS RISK ANALYSIS?

Risk analysis is a process by which the appropriate responsible body (often the government itself, or government-appointed) may deal with matters which pose a potential danger. It is generally understood to mean that the process will be managed along certain more or less standard lines. Although risk analysis has been used for examining the risks involved in such fields as nuclear reactors, chemical emissions from industrial processes and accidents, and general environmental issues for over twenty years now, its use in the veterinary sphere is relatively recent.

Risk analysis terminology

Its use in such a wide variety of disciplines has resulted in a number of different terminologies and this can, and does, cause confusion (Ahl et al., 1993). Even within the veterinary field, there is no uniformity.

The terminology we use defines risk analysis as a process which comprises hazard identification, risk assessment, risk management and risk communication, with the following meanings:-

- Hazard: Something which is potentially harmful, to humans, other animals, plants or the environment. If no hazard is identified, then there is no risk.

- Risk assessment: The process of evaluating the risk resulting from a hazard. Where data is available a quantitative risk assessment (QRA) may be undertaken, to evaluate both the amount of damage, and the likelihood of its occurrence.

- Risk management: Utilises risk assessment results plus the risk managers judgement to balance potential benefits against assessed risks, to reach decisions and formulate policy - which may include a requirement for risk reduction.

- Risk communication: An open information exchange between risk assessors, risk managers, and all those affected by both the risk and the decisions taken.

We would ideally expect risk assessors and risk managers to be different people, and this is generally the case. It should also be clear that risk analysis does not give a single 'correct' answer to a problem, but is a collaborative exercise utilising data and facts, plus opinions and judgements from a broad variety of perspectives.

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So - what is risk?

Risk implies that several different outcomes are possible from the situation being considered, and that one or more of these outcomes is unwanted. There is also uncertainty about which outcome/s will occur. For risk assessment all these factors apply and, in addition, there is the necessity for a systematic evaluation process. For QRA this will give the probability or frequency of each outcome.

ADVERSE PERCEPTIONS OF RISK ANALYSIS.

Risk analysis is a discipline which attempts to systematise and introduce more effective methods, some of them quantitative, to a process which has been carried out by governments and their advisors for many years. As such it bears comparison to the position of epidemiology in medicine and veterinary medicine some twenty years ago, and has caused some similar reactions.

Adverse perceptions based on lack of knowledge.

• We don't need it: There is often no perceived necessity for an alternative methodology, and this can lead to scepticism and lack of interest in what might be achieved with this approach.

• We don't like it: The distinction between risk analysis and risk assessment may not be appreciated, resulting in a suspicion that a model's numerical output might be used to replace the judgement required to frame policy, and even replace policymakers themselves.

• We don't understand it: Those without a mathematical background or training often view with distrust anything which looks too mathematical.

Adverse perceptions based on a desire to keep the status-quo.

Once a risk reduction measure has been imposed, and is widely believed to be effective, the psychological and potential political effects of removal of that safeguard may make any change difficult, whatever the demonstrated risks for current and alternative practices.

ZERO RISK VERSUS ACCEPTABLE RISK

Movement of animals and their products has long been recognised as having the potential to spread infection. Traditional methods of risk management, particularly when considering international movement, have tended to rely on zero-risk policies when considering whether imports should be allowed into a disease free area. Recent developments in international trade mean that this is no longer acceptable, and disease risks must be balanced against trading benefits (Pritchard et al., 1995), bringing into prominence the concept of acceptable risk.

Some traditional methods of risk management rely on the pragmatic use of tests of limited sensitivity so that positives can always be rejected. In the situation where an infectious organism is ubiquitous, the result of a test with a high level of sensitivity has a high probability of being positive, rendering zero-risk policies impracticable. For example, the microbiological sampling of only small samples from large consignments of feedstuffs is of limited sensitivity and allows a proportion of consignments to pass the infection test, whereas indefinitely large samples would always include a positive result, and no consignment could be accepted. This strategy completely avoids the issue of what is acceptable risk, but this is a short-sighted strategy. It is now becoming accepted that it is more proper to address that issue directly than to avoid it.

Many factors are involved in agreements regarding the acceptability of any given level of risk, particularly since those bearing the risk are often not those receiving the major benefits but, by implication, to negotiate over whether a risk is acceptable requires primary agreement, by all those involved in the negotiations, on the magnitude of that risk.

OVERCOMING ADVERSE PERCEPTIONS

By describing why we have become involved in risk analysis, and explaining the underlying terminology and methods used in risk analysis and particularly, quantitative risk assessment, many of these objections can be overcome. When doing this we have seen a gradual shift in perception, with a willingness to consider the role that risk analysis might play in decision making, and the role of risk assessment in providing information to facilitate that decision making.

The remainder of this paper outlines why we have become involved, and then focuses on describing the methods of quantitative risk assessment, including the potential pitfalls, and how these methods apply to our projects to date.

WHY ARE WE INVOLVED IN RISK ANALYSIS?

Recent developments

In recent years risk analysis has been identified as applicable to veterinary issues in two main areas; international trade in animals and animal products, where the possibility of importing disease along with these products has long been recognised, and food hygiene, to examine toxic residues and infectious organisms in meat and meat products.

Concurrently, there has been a methodological development in the techniques of quantitative risk assessment and it is this with which our group is particularly involved. Risk assessment is systematic and well documented giving the transparency necessary for independent critical evaluation. The inputs required for quantitative risk assessment highlight any crucial data deficiencies allowing initiation of data collection, where required, to evaluate and manage a risk. In addition, there is a distinct separation between the quantitative assessment performed by the risk assessor, and the consideration of whether that risk is acceptable, which is a question of judgement.

International trading agreements

The consideration of whether a risk is acceptable is, increasingly, a matter of international negotiation and this is the province of the General Agreement on Tariff and Trade (GATT), which was originally established in 1947. It was only after the Uruguay round, launched in 1986, that agricultural issues were brought fully under its rules (for a review, see Scudamore, 1995). Negotiations were protracted and contentious but eventually culminated in the Final Act, which came into force only on 1 January 1995 and set up the World Trade Organisation (WTO), which oversees the workings of the agreements, binding on all members, made in the Uruguay round.

For animal health, the Agreement on Sanitary and Phytosanitary (SPS) Measures is the most important, allowing countries to give food safety and animal health priority over trade requirements only if a scientific basis for that priority can be demonstrated. Although each country can determine the level of risk appropriate to its own conditions, this must be based on defendable assessments available for objective evaluation. For this, GATT advocates the use of the systematic transparent repeatability of risk assessment methods, for which the Office International des Epizootics (OIE) is now charged by the WTO with a key standard-setting role (WTO, 1995).

In consequence, Scudamore (1995) concludes that "There is no doubt that the impact of international trade agreements will stimulate the need for methodical risk analysis by member countries". Clearly - we do need it, and it would be prudent to have a readily available source of expertise. It is in the light of these requirements, and the fact that risk assessment involves quantitative determination of likelihoods and is thus analogous to epidemiology, that the CVL Epidemiology Department, had already set up, and is now expanding, its risk assessment facility.

AN OUTLINE OF RISK ASSESSMENT METHODOLOGY

Development of the quantitative risk assessment model

A sequence of events must occur to produce a risk.

• First, there must be a risk 'release' source. Examples include:-

An industrial plant releasing radiation or chemical pollutants,
An automobile or aircraft capable of 'releasing' an accident,
An animal capable of 'releasing' a zoonotic disease to humans,
An abattoir 'releasing' bacteriologically infected carcasses from its premises.

Often, the source may not be singular but will be a population, for example of abattoirs or of potentially infected animals.

• Second, there must be an exposure to that risk, either by humans, other animals, plants or the environment. In addition, there may be different categories amongst the exposed. Occupation as a nuclear physicist, distance of residence from a chemical plant, willingness to fly, and vegetarianism, for example, may all affect appropriate exposures.

• Thirdly, there must be at least one unwanted consequence to the exposure, the most common being death, sickness, injury, and environmental pollution or degradation. In addition, those events which are consequences for one exposed group may function as the risk release source for another group. For example, foxes may 'release' rabies infection to exposed cattle, with the consequence that some cattle develop rabies. These then function as a risk 'release' source for exposed humans.

For each of these events, a distribution of likely values is determined. The variety of methods used in assessing these three events can be systematically categorised, although overlap exists. Table 1 gives examples of some of these; for further explanation of these modelling methods, see Covello and Merkhofer (1993).

The results from assessing these three events are then integrated to produce the overall risk estimate or assessment. At this stage, it is necessary to ensure continuity in the risk being assessed; for example, the assessment of the consequences of a severe automobile accident should not be coupled with the assessment for exposure to all automobile accidents; they must be evaluated separately. For relatively uncomplicated pathways, the three stages may not be explicitly identified, the integration being implicit in the overall method. Either way, the final result is the integrated risk assessment, in outlined in fig.1.

Table 1. Categorisation of some commonly used risk assessment methods
(after Covello & Merkhofer, 1993)

Release assessment	Exposure assessment	Consequence assessment
Monitoring	Personal exposure monitors	Health surveillance
Performance testing	Site monitoring	Animal testing
Accident investigation	Biologic monitoring	Human testing
Classical statistical methods	Laboratory testing	Epidemiological studies
Bayesian statistical methods	Dose calculation	Dose-response models
Failure analysis	Population-at-risk models	Pharmacokinetic models
Event trees	Pollutant transport-and-fate	Field testing
Biological models	models	Ecological effect models
Discharge models		

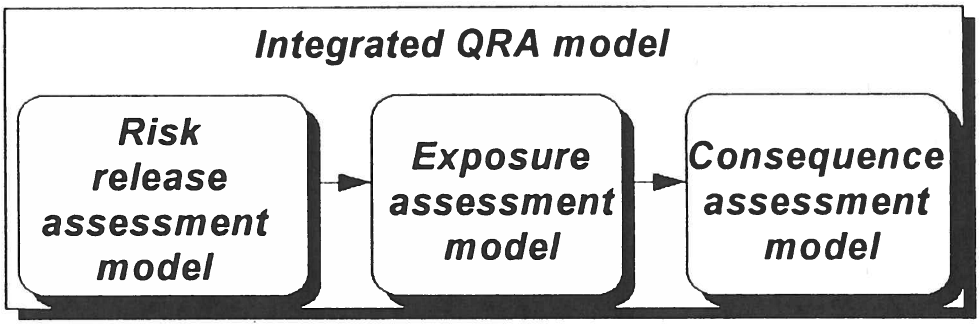

Fig. 1. Integrated quantitative risk assessment model

Uncertainty and variability in quantitative risk assessment

For integrated quantitative risk assessment the construction of a model, however simple, of the pathways from risk source to consequence is necessary. The model will contain data inputs, and outputs in the form of probabilities or frequencies of the possible consequences. Implicit in this are potential sources of both uncertainty and variability (for a review, see Morgan and Henrion, 1990), as follows:-

• Model uncertainty: Parts of the pathway may be unknown entirely, or there may be several candidates. One solution is to include each possible pathway, as alternatives, into the final model, and assign a probability to each.

• Input uncertainty: Here, the true value of the input is unknown. Possible examples include:-

The number of people living near a nuclear power plant,
The low-level dose-response effects for a potential carcinogen,
The number of infected carcasses leaving a poultry slaughterhouse,
The incidence of tuberculosis in a particular area.

• Variability: When an input may take one value from a particular (well-characterised) distribution, which is used directly as the input. Possible examples include:-

Height, weight, and age of humans and some other species,
Diurnal temperature fluctuations,
Some nutritional intake data.

Constructing distributions

Traditionally, input uncertainty is dealt with by taking the single-value worst-case estimate. In quantitative risk assessment, the extent of that uncertainty can be entered into the model in the form of a frequency distribution, maximising the use of available information.

There are two basic ways of deriving the distribution. The first is directly from observed or experimental data. For example the binomial distribution gives the probability distribution for the number of infected animals in a batch of known size, where each animal has a known probability of being infected, or the exponential distribution, which describes the probable lifetime of a device with a constant probability of failure, and a known mean time to failure.

The second method is to use 'expert' opinion, and where little hard data exist, this is often essential. Potential pitfalls include choice of appropriate experts, eliciting opinions without bias, and combining or choosing between different opinions. Most people are not used to thinking in terms of probability distributions, and may require visual aids. Some people may think expressing uncertainty indicates a lack of expertise, and be unwilling to do so. Bias may already exist or may easily be introduced by poor questioning technique. For example, asking about the modal value first tends to produce 'anchoring' bias. Where opinions differ sharply, it may be necessary to incorporate each, weighting by probability.

Variability may exist with or without uncertainty. Food intakes across a species, for example, are generally both variable and uncertain. Whilst surveys and questionnaires can be used to reduce the amount of uncertainty if necessary, variability will remain. An additional point regarding variability concerns perspective and many of the inputs given as examples above may be either variable or uncertain, depending on the exact question being asked. If the risk under investigation concerns a population then a distribution of, say, weight will represent variability. If, however, the risk to one particular person is under investigation, but the specific weight of that person is unknown, then that same distribution will now represent uncertainty. When both are present, mixing of the two without due regard to their different meanings may result in misinterpretation of the outputs, and one way of addressing this will be discussed later.

Frequency distributions commonly used in risk assessment may be represented by any of the standard probability distributions, both continuous and discrete. Some examples include the normal, log-normal, uniform, beta, Poisson, general and triangular distributions. The triangular distribution in particular is often found convenient to use, and is defined by three points; the minimum, most likely and maximum values, with zero probability at each end and straight lines joining each to the most likely. However, it has been suggested that this gives too much weight to certain parts of the distribution distant from the mode and that when these three pieces of information only are available, the beta-pert distribution may be more appropriate.

Propagation of uncertainty and variability through the model

With many model inputs being in the form of frequency distributions, a method of retaining these distributions and propagating them through the model is required to give outputs (i.e. the risk estimates wanted) also in the form of frequency or probability distributions as illustrated in fig. 2.

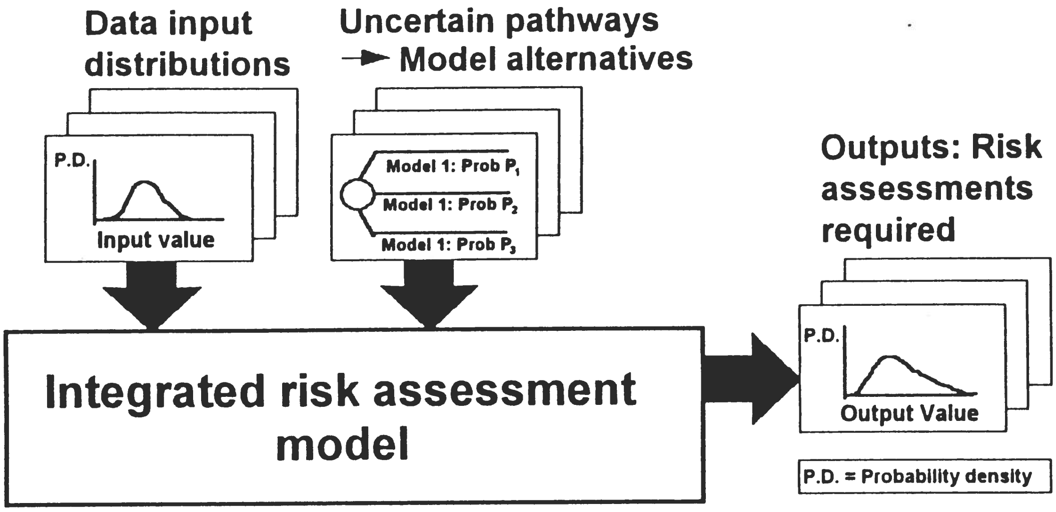

Fig. 2 Propagation of distributions through the model
(after Covello & Merkhofer, 1993)

There are a number of possible approaches (see Morgan and Henrion, 1990) some having been developed into commercially available software packages, and some of which are based on spreadsheet modelling although more complex packages exist, for example Analytica (previously known as Demos). A spreadsheet model represents the rate or probability of the outcome as a simple calculation, for example the rate of importation of infected animals may be represented as *(the annual number presented for import) x (the proportion infected) x (the probability of an infected animal not being detected by pre- or post- import testing)*. The spreadsheet will perform the calculation for any given value of the inputs (in italics); by using a spreadsheet 'add-on' a distribution of values may be entered for any of the inputs.

The best known examples are @Risk and Crystal Ball, both of which utilise the Monte Carlo simulation method. The model is designed and inputs are entered, where necessary as distributions. Outputs are selected. Each simulation, or 'run' of the model performs the calculations as defined, and produces a value for each selected output. Where the input is defined as a distribution, each 'run' randomly selects a value from that distribution for use as the input. A large number of runs results in a large number of randomly selected inputs producing outputs which are thus a random sample from the overall probability distribution for that output. These are collected together and built up into an output distribution which can be illustrated graphically and analysed statistically, giving much more information about the probability of an outcome than would a single-point estimate taken from a worst-case scenario.

One method of differentiating between variability and uncertainty in the inputs is to construct a 'two-dimensional' model, which can be done in spreadsheet software by using a macro, where holding variable values constant gives a distribution for the output uncertainty associated with those variables, and this is repeated over the distribution of variable values, to give an output distribution where 'slices' represent the distribution of uncertainty for one particular set of variables (for review of methods, see Frey et al, 1995). It may not be possible to characterise output variability without considerable uncertainty 'noise'.

THE CURRENT SITUATION: VETERINARY APPLICATION OF RISK ASSESSMENT

International trade and movement of animals and animal products

Application in the field of the import of animals and animal products has already been mentioned. MacDiarmid (1991) reviewed the risks of importation of a wide range of meats and meat products into

New Zealand, using the systematic methodology of risk assessment, but did not undertake quantitative assessments. He did, however, reproduce the quantitative method developed by Dr Tony Forman at the Australian Animal Health Laboratory to assess the risks for TGE in Canadian pigmeat.

The OIE (1993) has devoted an issue of its regular Scientific and Technical Review to Risk analysis, animal health and trade, comprising 16 papers including several describing quantitative assessment methods. Sutmoller and Wrathall (1995) have recently published a particularly detailed account of their method of the quantitative assessment of the risk of disease transmission by bovine embryo transfer, including the proposed scenario tree on which their model is based, the input distributions used, and the distributions produced at each stage by Monte Carlo propagation of uncertainty through their model.

An additional area for which quantitative risk assessment is likely to have a future role concerns rapid international movement of all types (humans, other animals, plants and other goods) and the undetected carriage upon them of exotic pests and parasites, and their ability to survive in different climatic conditions.

Meat hygiene

The potential application of risk analysis to meat hygiene was discussed by Hathaway (1993). Quantitative assessment here forms a section of a larger model for human food risk assessments.

Quantitatively assessing the risks of chemical residues in meat, both from treatments applied directly to the animal, and by environmental toxins and pollutants in soil, air, and animal feedstuffs, is a newly emerging area of application. Work on other parts of the foodchain is ongoing, for example method development for assessment of the levels of various toxins and pollutants in plants (McKone et al., 1995), but we have found little evidence of comparable work in livestock, and a number of methodological issues remain.

An outline model for the quantitative assessment of microbiological hazards in poultry has been described (Covello and Merkhofer, 1993) and Christiansen and Richards of this department have recently undertaken an unpublished study into the feasibility of applying risk assessment methods to biological hazards in red meat.

RISK ASSESSMENT TOPICS WITH WHICH WE ARE CURRENTLY INVOLVED

In order to explore the potential for development of this expanding field in contexts relevant to our work, we have been examining the methodological and practical issues in applying risk assessment to a number of specific topics, including examples from all the categories described.

Animal import issues include a preliminary examination of the methodology and sources of available data for risk assessments involving particular aspects of rabies in cats and dogs, *Brucella abortus* in cattle, and *Mycobacterium bovis* in cattle.

For meat hygiene and toxicology, we are looking first at the problem of cadmium levels in the kidneys of cattle. We are developing a model to determine the likely relative importance of different sources or routes of cadmium intake in determining the concentration in the kidney at slaughter. Our involvement with microbiological hazard risk assessment is the subject of another paper being presented at this conference.

The following is a brief description of the identified major methodological and practical issues in those topics examined. The major methodological issues can be identified by reference back to the risk assessment principles outlined earlier.

Identifying/defining the type of assessment being undertaken

Is the assessment for release, exposure, consequence or implicitly integrated risk assessment? Where a specific question is asked, as in most of our projects, there may be no choice in this. Where choice exists, there is an obvious argument for assessing the consequences first, followed by the exposure, and only lastly the release.

For the import-related projects, we are first considering appropriate methodology for the risk 'release' assessment section of an integrated assessment model i.e. the probability of infection import into Britain. With respect to both rabies and *M.Bovis*, this is because the questions being asked involve comparing risk levels at import before and after possible import regulation changes. For *B.Abortus*, our focus was to examine potential import data sources, best facilitated by looking at a baseline import risk level. Assessments of the exposure of indigenous populations, and the disease consequences of such exposure are separate exercises.

For the project involving cadmium in kidneys, the particular assessment identified as required by our toxicology colleagues, is actually an exposure assessment. Specifically, the exposure of the kidneys of cattle to cadmium, given that cadmium is already present in the environment. The consequences of this exposure are not considered in this model.

Deciding on the most appropriate model type.

For all the animal import projects, the method used comprises the development of an appropriate scenario tree, assigning a probability (generally as a distribution) to each event in that scenario tree, and estimating the probability (again, as a distribution) of the final outcome. A very generalised outline scenario tree is shown in fig. 3.

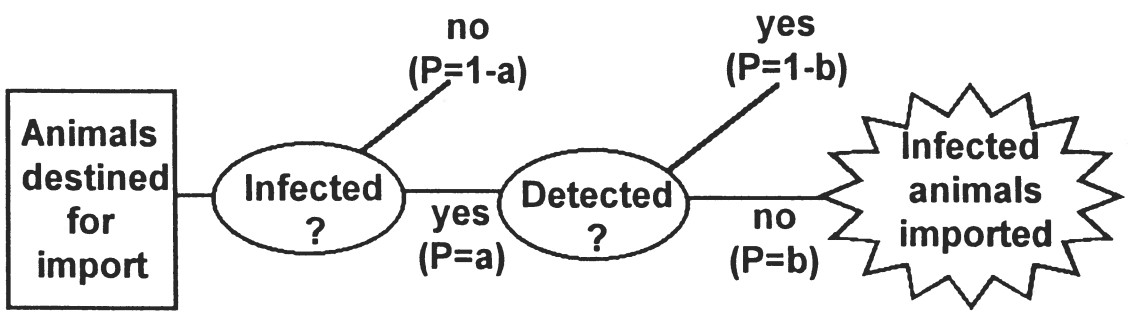

Fig. 3 Generalised scenario tree for animal import risk assessment

This looks deceptively simple, giving the probability of importing infection as *(distribution a) x (distribution b)*, but the model then requires tailoring to the specific case. One particular issue which affects the exact form of the model is whether the risk being evaluated is that of an individual animal being infected, or whether infection is present in a group of animals.

Additional modifications depend upon the particular case. For example, with rabies, the specific question being asked is: "For dogs and cats entering Great Britain, will the replacement of six months quarantine by vaccination and blood testing increase the risk of an infected cat or dog entering the country ?" Being in quarantine is here defined as having not yet entered the country, and we make the initial assumption that no other import factors are altered.

This is therefore a risk comparison problem, and we are interested in the risk of any one imported animal being infected. One method is to define a baseline model (no safeguard in place), and assess the risk of an infected animal import. To this is then added, separately, the two proposed risk-reduction methods (one reducing the likelihood of infection, the other detecting infection), the risk re-assessed for each, and a direct comparison made. Three separate models are therefore utilised, and the outputs compared.

In contrast, our starting point for the exposure assessment for cadmium in kidneys is a biological model of the fate of cadmium from its point of contact with an animal. In constructing the biological model, one major problem which had to be addressed was lack of detailed biochemical pathway information. The simplified assessment model being evaluated at present is based on this biological model, and the first stage is to model the kidney cadmium concentration by day in the life of an individual animal, onto which will be superimposed an appropriate age at slaughter distribution, to give a distribution of kidney concentration at slaughter.

Handling uncertainty and variability in the input data.

Once again, using rabies as the example, the rabies risk assessment inputs include:-

•Baseline probability of infection, dependent on the prevalence of infection in the animals destined for export, which, due to under-reporting, of cases and lack of denominator data will be uncertain.

•Probability of detection of infection in quarantine, dependent upon the incubation period which is uncertain, at least in its extremities, and may well differ for cats and dogs, and is also variable.

•Probability of infection reduction by vaccination, which may be altered by, for example age, species, and vaccination type, resulting in uncertainty. Blood testing as a means of identifying successfully vaccinated animals is also subject to uncertainty in its sensitivity and specificity.

Most risk assessment inputs are associated with ranges and must be represented by appropriately selected distributions. In addition, propagation through the model is necessary. One method, Monte Carlo simulation, has already been described, but others may sometimes be more appropriate.

Where there is uncertainty over the values of key parameters in a risk assessment model then particular attention needs to be paid to the method of combination of these uncertainty distributions. Sometimes correlations should be introduced between the distributions, which can be done in spreadsheet modelling, although multidimensional uncertainty distributions are difficult to interpret. It is better, if possible to ensure that the model is parameterised in terms which can reasonably be described as independent.

If spreadsheet modelling is to be properly applied to a process which will be replicated many times, as for the importation of animals, or indeed for most examples of interest, care must be taken that the model does reflect uncertainty over the average outcome rather than the variability between individual imports. In simple models this distinction does not matter but in more complex examples it may become a more important consideration.

Additional factors which should be considered.

Subsequent to the initial model development, it may be necessary to consider the incorporation of additional factors. For rabies, examples include:-

• Total import numbers and the effect of any regulatory changes, directly or via costs, on that number. Although the risk per animal will not necessarily change (although it might, if the population from which imports are derived changes, and that also needs consideration), the rate of import is relevant to total risk.

• Ease of transit from third countries.

• Illegal imports, the risks for which may be different to legal imports.

• The related practical issues of animal and test sample identification and documentation, tracing and recording.

Judgement and choice in quantitative risk assessment.

It is apparent that in the development of a quantitative risk assessment, there are many methodological issues involved, and many points where the assessors choice and judgement must be used. Complete documentation and referencing of all data sources and methods is therefore essential for subsequent evaluation of the outputs. In addition, this allows for identification of areas of data deficiency, allowing systems to be put in place for data collection as necessary, and this is also an important function of quantitative risk assessment.

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THE APPLICATION OF HYBRID INFORMATION SYSTEMS TO DECISION SUPPORT IN THE VETERINARY AND AGRICULTURAL DOMAINS

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Any attempt to provide computer-based decision support within the veterinary and agricultural sectors must allow for information integration. This has a particular impact on projects which use various types of knowledge-based tools and mathematical models to develop hybrid systems. Recent projects adopting an integrated approach to information usage in the areas of animal health, welfare and production have demonstrated a number of advantages, including economy of effort, benefits of a team approach, increased user compliance and the ability to identify areas of inadequate knowledge to provide a focus for further research. While there are definite benefits in taking such a holistic approach, a number of problems are associated with the integration of these tools into hybrid information systems (HIS) (McKendrick et al., 1994). Uncertain knowledge, lack of consensus, inadequate data and a reliance on information technology infrastructure cause technical problems while cultural and political issues must also be tackled. In addition consideration must be given to the issue of knowledge and model validation, a task which will often be much more complex for an HIS than when a single problem focus has been adopted. Consideration must also be given to mechanisms for transferring HIS from a largely research-based audience to users in the field.

THE NATURE OF DECISION SUPPORT

All computer based systems are basically concerned with the storage and manipulation of data. However, if data are to be useful they must be structured in an appropriate manner. Only then do they become meaningful enough to be described as information. Often, the information is structured to aid some decision

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making process. To do this it is necessary to provide mathematical modelling and statistical tools to analyse the information and summarise the suitability of different intervention strategies. The integration of database and modelling tools, to construct a product which reflects the needs of decision makers has led to the development of a class of systems known as decision support systems (DSS) (Sprague & Carlson, 1982). However, there are certain types of data which do not fit easily into classically structured information systems (including DSS), two of the best examples being text-based information and heuristics or rules of thumb. These types of unstructured data are managed within information retrieval, hypertext and knowledge-based systems. A prerequisite for the provision of a flexible DSS is that methods must be found to integrate information and knowledge from both structured and unstructured sources. Therefore, although a number of systems referred to in this paper could be described as DSS, the term "hybrid information system" (HIS) is used to emphasise the importance of this integration of diverse types of information and management system.

It is important to stress that the types of system being constructed are not decision making systems. Some of the components which are being incorporated, such as mathematical models and expert systems, have at times been misinterpreted as decision-making devices. However, the idea of a computer system which tells the user what to do is a discredited one. Hybrid information systems do not supplant the decision maker. They should provide information in a user-friendly manner, enabling users to make use of as much (or as little) of the available resources as they wish, allowing them to make better decisions.

SOME OBSERVATIONS ON INTEGRATING INFORMATION

Typical contributors to veterinary and agricultural HIS will be producers, veterinarians, scientists and policy makers. The information which is supplied will be most readily summarised in different ways, depending on the nature of the different topics under investigation. Consequently, information will be delivered in many diverse forms. These might include structured formats such as data contained in databases; partially structured formats such as expert rules and mathematical equations and unstructured formats such as textbooks and research papers. The available pool of expertise is therefore large and heterogeneous. A number of tools, such as database management systems, expert systems, mathematical models and multimedia systems exist to aid the user in the handling of different types of information. In the area of animal health and production such tools have typically been focused on specific user groups and applied to narrow knowledge domains, in isolation from other techniques. The users of a database management system may find it hard to understand the outputs from a system when these are presented as uncontextualised, uninterpreted data elements. A mathematical model can be used to produce estimates of otherwise unobservable pieces of information, such as risk of infection, but users may find it hard to accept such predictions without suitable guidance. An expert system, in mimicking the decision making process of human experts, may not be able to complete its inferential process without access to information contained in a related database.

Therefore, potential exists for the integration of different tools across a wide knowledge set containing diverse information types. This diversity has often led information providers to the conclusion that each 'user need - information type' pairing must be served by a separate system. While it would be foolish to ignore the fact that the needs of each user must be taken into account during design and implementation, the extension of this client-focused view to the creation of a large number of individual systems brings with it a number of problems. A user may be primarily interested in one topic which is apparently summarised within a single structure and hence is well served by a single information tool. However, tools are often deficient when used in isolation; their full potential can only be realised through integration, and so a primary tool is likely to benefit from being linked to other, related materials. The integration of tools alone is not sufficient to ensure the effective and efficient use of information, consideration must also be given to the underlying information and knowledge structures.

CONCEPTUAL INTEGRATION

It can be argued that differences in user information requirements may be more apparent than real, representing only different routes through the same information structure. The concept of information integration describes an attempt to organise data and knowledge into a single cohesive unit. The resultant complexity necessitates the provision of tools which deliver appropriate access to, and navigation within, the information structure. Apart from any theoretical arguments as to the completeness or elegance of this approach, this type of information integration has important economic implications. Rather than assuming that each group of users has unique information needs requiring separate systems, one can assume that these needs can be met from different viewpoints or dimensions on the same underlying information continuum. If this is the case then maintaining the information in a unified but suitably flexible manner will enable differing user perspectives to be captured within a common information structure.

This type of conceptual integration was pioneered in the area of librarianship with the development of classification systems such as Dewey and UDC to give conceptual content tags to books. This work was continued and expanded into the discipline of Information Science, as tools such as thesauri and faceted classification systems were introduced to supplement the earlier hierarchical or enumerative approaches (Revie & Smart, 1992). Because of its origins, most of the work in the area of information retrieval has been focused on dealing with unstructured, textual information. However, recently it has been noted that completed classifications for a given domain can be used to index information and knowledge of other types, and form the basis of meta-data models. The other major use of such classification schemes has been in the definition of common data formats for database storage. Within the veterinary domain, the most commonly used format was the Standard

Nomenclature of Veterinary Diseases and Operations (SNVDO) (Priester, 1971), which is utilised in the North American Veterinary Medical Data Base (VMDB) and the British Veterinary Investigation Diagnosis Analyses (VIDA), among others.

Research into appropriate meta-models continues to be led by work within the medical domain, the SNOVET classification being founded on medical equivalents and since combined into the more general SNOMED (Systematised Nomenclature of Medicine) (Cote et al., 1993). It is also within the medical domain that the most notable attempts have been made to move classification tools beyond both bibliographic indexing and data formatting. A notable effort in this area is the GALEN project (Rada et al., 1992), although developments are still at an early stage. There has also been a resurgence of interest in the area of conceptual mapping as researchers look for methods to index and provide navigation through the wide range of information resources becoming available on the World Wide Web and emergent digital libraries (Digital Libraries Project, 1995). It is hoped that insights gained from these areas will aid in the development of a fuller theoretical framework, which will in turn underpin the work of integration being carried out in the area of veterinary informatics.

BENEFITS OF INTEGRATION

The benefits which arise from the integration process which underlies the development of an HIS fall into three major classes.

First, the system will potentially be much more effective. Situations which require decision support are by definition complex, involving many interrelated factors which require to be viewed in a unified manner. Consider the case of African dairy farming, where increases in production require the simultaneous adoption of policies relating to disease control, livestock breeding and animal nutrition. A piecemeal strategy which addresses any of these interconnected topics in isolation would be much less likely to succeed. Also, one of the major themes of sustainability is the need to view systems in a holistic rather than an atomistic fashion, ensuring that the 'whole' is not obscured by an over-emphasis on individual parts of the picture. For both of these reasons, it is necessary to provide decision support over a wide range of topics. System integration is a necessary prerequisite for any such holistic treatment of information.

An HIS also gains in effectiveness through synergistic effects. At one extreme, this synergy might be no more than a function of completeness. If an advice module may occasionally touch upon a topic which is strictly outside its expert domain, it is clearly preferable that a further module be available to continue the advice session, rather than the user being forced to ignore what might be an important line of inquiry. An example of this would be given by decision support for the control of African tick-borne diseases: advice modules on immunisation, tick control and chemotherapy are so intimately linked that if they were not hybridised into a single system, the resulting 'stand-alone' expert systems would be incapable of providing useful advice.

At the other extreme, the feedback of information between different types of advice modules can create a 'virtuous circle', in which more value is progressively added to the information. This has been observed in our equine health and welfare system, EQWISE (Mellor et al., 1994). A mathematical model which predicts the likelihood of a horse having cyathostomiasis would, in isolation, be little more than a mathematical curiosity, but when it is linked with hypertext libraries and a Geographical Information System containing disease prevalence maps, it becomes a tool of real educational value. This is generally true of many mathematical models and statistical techniques which can be used to add value to clinical and epidemiological data. Such techniques have most often been presented in a form suitable only for the use by the mathematically literate. The ordinary user has had little chance of following the logic of the technique and even less chance of making optimal use of it. Embedded within an HIS, mathematical software has the potential to add value to information which is moving around the system, while other information tools make mathematical techniques available to any user. HIS provide a favourable environment for the development of such synergistic systems.

The effectiveness of any putative HIS is also enhanced in a more subtle manner. A system is only truly effective if it provides support across a sufficiently complete problem domain. Where this domain is complex and multi-faceted, individual sub-topics, considered in isolation, may appear dauntingly refractory to decision support. However, where a hybrid system is being developed, attention is focused on the entire problem domain. When a single sub-topic is considered, the underlying developmental assumption becomes, "how can a tool for this subject be fitted into the system?" rather than the more negative, "can I build a tool for this subject?". In so far as a hybrid system provides a focus around which researchers may develop their ideas and therefore perhaps encourages the growth of any system into relevant subject areas, the HIS framework may promote the creation of more effective DSS.

The second type of benefit which a DSS gains from hybridisation is that of increased efficiency. While the system is being used, integrated information management will ensure that whenever a module requires a piece of information which has already been entered into another component of the system or which is stored in a database within the HIS, the relevant information will be passed to the active module. This has obvious benefits in reducing the effort which is demanded of users of the system.

Complex situations are described by information of differing types, scale, scope and structure. It is likely that for each subject of interest in a decision support situation, one type of tool will be found to be more suitable than the others. The incorporation of these diverse classes of information within one tool or into a single type of knowledge representation would remove the ability of the system to make full use of the richness of this diversity of information. By contrast, within a hybrid

DSS, the most appropriate knowledge tool can be selected for each information class. Rule-based expert systems provide a means of structuring qualitative knowledge which has been gathered from experts. Belief networks update quantitative, probabilistic information in order to express knowledge about the relative likelihood of different scenarios. Mathematical models utilise qualitative, factual information in the formulation of the mathematical rules which describe how the model will evolve, while using quantitative data to estimate the required numerical parameters. Optimum utility is gained from each type of tool within the overall system; this can only be fostered within an HIS.

A further efficiency gain can arise from the policy of selecting an appropriate information tool to handle each separate subject. Since the developer is not attempting to distort the information structure to fit it into an inappropriate tool, it is likely that the tool will require little or no modification to handle the information. Hence, it is reasonable to expect that relatively standardised information tools can be utilised within an HIS. The use of such generic pieces of software should produce economies of scale in the production of DSS, where software code can be written, technically validated and used in a variety of different contexts. Development effort can be focused on the production of a small number of high quality generic tools rather than the design of a larger number of less effective, overly specific tools.

Efficiency and effectiveness are both promoted by another aspect of HIS development procedure. The process of constructing an integrated system enforces contact between the creators of different types of decision support tools, such as expert systems, mathematical models and databases. The specialist nature of these tools requires that the developers of such modules be drawn from different disciplines. The resulting interactions between experts from different backgrounds maximises the opportunity for fruitful cross-fertilisation, as well as making team members more aware of the limitations of their own discipline and past perceptions.

The third major class of benefits which arise from the development of a hybrid system relate to the effect on scientists who contribute to the knowledge acquisition sessions which underlie any DSS. Just as the construction of models within a single subject area will highlight topics which require further investigation, the linking of diverse areas will reveal issues which are poorly understood. These topics may not clearly fall within the boundaries of an individual scientific subject domain. The development of an HIS encourages interaction between experts in the various topic domains under study and highlights areas of potentially useful collaborative research.

PROBLEMS OF INTEGRATION

While there are benefits to be gained from the use of HIS, any attempt to structure information across a wider and more complex subject domain leads to a number of problems. These difficulties arise even at the knowledge acquisition phase. It is well documented (Hart, 1986) that the potential loss of exclusivity of knowledge by domain experts may reduce their willingness to participate in the knowledge acquisition process. This is compounded within a hybrid framework because the expert is often required to move to the boundaries of his or her subject, and beyond. This is a 'high risk' activity for any scientist, with increased intellectual exposure as one moves away from one's specialism. The willing co-operation of experts is essential to all knowledge acquisition (Goodall, 1985) and this will become increasingly difficult to achieve if the expert feels threatened. This is not a problem simply relating to the individual scientist, as an emphasis on single disciplines is often reflected in the 'atomistic' structure of research management. These structures will often mitigate against the creation of an integrated product which requires an integrated development team and so appropriate cross-disciplinary management mechanisms must be set up for HIS development to be successful.

Once the knowledge has been successfully acquired, a number of technical problems relating to the representation of this knowledge arise. In particular, it is necessary to transfer knowledge between tools which utilise radically different formats for the storage and manipulation of information. In order to facilitate this transfer of knowledge a common set of conceptual structures, or at minimum a 'translation service' between synonymous structures, is required. Since systems use widely varying data structures, vocabularies, tools and approaches, the development of such mechanisms is likely to prove problematic. The GALEN project illustrates one attempt to develop an *interlingua* between different information systems in the domain of human medicine.

Identifying and defining an appropriate scope for a system is difficult when a product is not market-led. By definition, an HIS is unlikely to fit any existing market niche so part of the developers' task is to educate the potential users as to new ways in which to utilise the wider range of knowledge embedded in such systems. Creating a thirst for knowledge brings with it the responsibility of providing a source to satisfy such demand, while remaining cognisant of the need to avoid swamping the naive user with too much information.

The final stage of the development of a DSS involves the validation of all its constituent elements. Hybridicity complicates this process in that the validation procedure for each component will differ according to the nature of the data and models which it contains. For example, the validation of a mathematical model will require observations of a much more quantified nature than those used for the validation of a heuristic rule-based system. The use within an HIS of information drawn from a range of knowledge domains creates fresh problems in validating those elements which traditionally do not fit within a well-defined subject domain. In addition, if an HIS is to maintain its utility the process of validation cannot be a one-off activity, as the knowledge contained within such a system should be dynamic. The system must actively encourage the continued capture and restructuring of knowledge as a range of users interact with it. If this information can be incorporated into the system it will add value and aid the validation process, in addition to making the advice much more credible to the user. However, any attempt to update the knowledge on a regular basis leads the developer to problems relating to editorial policy: Who should control updates; when are these appropriate; and what mechanisms exist to ensure that consensus is formed from divergent opinions? All of these issues are once again complicated by the fact that an HIS will require input from scientists from a broad range of disciplines.

'INTO THE FIELD'

Many of the benefits, and indeed problems, listed above can only be realised or overcome as systems move from the research environment into real world usage. Although the HIS described in this article differ from conventional DSS there are enough similarities to make a survey of progress in the area of DSS instructive for our case. Such a survey does not yield particularly encouraging results as the uptake of DSS in the veterinary and agricultural domain within Europe and North America has not been rapid. One country which appears to be atypical and has made substantial use of DSS in a number of veterinary and agricultural areas is New Zealand (Holmes & Macmillan, 1982; Morris et al., 1993; Kemp et al., 1994). While there may be many reasons for this it is interesting to note a response from New Zealand to the question, "why is it that...very few (DSS) have made the transition from research projects into practical viable tools?" Simon Woodward, of the New Zealand Pastoral Agricultural Research Institute, makes the following observation, "in the UK most 'DSS programs' seem to be research models with a bit of interface added, which often require pages of parameters to be filled in. In New Zealand each version of the software prototype is given to farmers for evaluation and so our DSS are very much tailored to the clients rather than the scientists." (Woodward, 1995). At the same time, he also makes the point that, "the underlying models are simple, the parameters biologically meaningful, and where possible taken from lookup tables by the software rather than entered by the user."

A number of the projects with which the authors have been involved would support the view that the end user's views must be paramount and that a close working relationship with potential users needs to be built up during the development of an HIS. For example, a number of our efforts to provide support to the African dairy sector had been successful from a research point of view but seemed to have little hope of making an impact on the farmer precisely because these farmers had no intention (or means) of moving towards computerisation. However, with the liberalisation of much of the agricultural sector (in particular milk production in Kenya) the managers of these enterprises are beginning to realise the importance of ensuring competent and effective management information and, for example, in large dairy co-operatives the volume of data implies the need for a computerised system. Thus the HIS can be 'sold' on the basis of how well certain elements within it meet the perceived needs for a management information type system with the more complex modelling and value added elements being introduced as a by-product of this more apparent requirement.

Potentially the largest problem in gaining widespread use of any system is the issue as how best to distribute the software. A number of options exist, the most appropriate depending on the situation. One option is to find a market partner product and distribute the system as part of an existing distribution scheme. For example, a system on production diseases in Africa may be attractive to an acaricide manufacturer who would view the product as gaining added value. The benefits of this approach are an existing customer network and consumer confidence in the product. However, these strengths are also weaknesses as failure of the product may also mean rejection of the system. Once again it is interesting to note the following comment with respect to DSS in New Zealand, "The software is effectively promoted by word of mouth from farmer to farmer." (Woodward, 1995).

The most important validation relies on field work and testing *in situ*. The fact that an HIS is used means that the process of validation through data capture and analysis is more effectively carried out. In addition to technical validation the system must be shown to provide commercial advantages to the user. Once again the integration of models and cost-benefit type analysis within an HIS mean that demonstration of this value can be more readily achieved.

CONCLUDING REMARKS

Most of the individual subsystems within hybrid systems are already used, though often in isolation, to assist decision makers in agriculture. The integration of these subsystems within a cohesive information matrix results in systems which provide enhanced efficiency and effectiveness relative to a suite of stand-alone decision support modules. There are of course potential problems, particularly in the areas of design, validation and distribution, but these are out-weighed by the benefits which accrue from successful hybridisation. In addition, a number of these limitations may be dealt with through the emergence of broader classification and indexing standards. This will facilitate the true integration of information and knowledge and the construction of hybrid information systems which allow users to interact with the knowledge base in a much more flexible manner.

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VETERINARY PUBLIC HEALTH
AND
FOOD SAFETY ASSURANCE

VEROTOXIGENIC *ESCHERICHIA COLI* O157 IN SCOTLAND

W J REILLY*

As part of routine surveillance the Scottish Centre for Infection and Environmental Health (SCIEH) receives reports from all medical and veterinary microbiological laboratories in Scotland. The first human isolate of Verotoxigenic *Escherichia coli* O157 (VTEC) in Scotland was reported to SCIEH in 1984, some two years after the first United Kingdom isolate. Since then the organism has also been recovered from cattle, food and water. In other parts of the world VTEC began to be reported at the same time. For example only a single isolate was reported in 1983 by the Centers for Disease Control and Prevention, Atlanta, out of 3000 strains examined (Riley et al, 1983). This indicates that this organism was not frequently associated with human disease before this date.

In Scotland VTEC can now be identified as the most important human gastrointestinal infection with a zoonotic potential. While numerically not as great as some of the other more traditional enteric zoonoses such as salmonella, campylobacter and cryptosporidium the clinical consequences of VTEC make up for any numerical shortfall. As with most enteric infections the spectrum of illness varies considerably and ranges from sub clinical through simple diarrhoea to haemorrhagic colitis. It is the added potential for the development of the haemolytic uraemic syndrome (HUS) that is of major concern. A substantial number of patients, usually children, develop renal failure. Not all of these are transient, and this can result in permanent renal failure or death. An estimation of the clinical importance can be made from the findings of a descriptive study carried out in Scotland during 1992/93 (Table 1) (J C M Sharp - personal communication).

Table 1. *E.coli* O157 extended surveillance study 1992-93

Number of cases investigated	139
Number of patients admitted to hospital	81 (59%)
Number of patients developing HUS	21 (15%)
Number of deaths	4

This paper will review the emergence of VTEC as a major pathogen in Scotland during the period 1984 to 1995 and will be based on laboratory returns and other surveillance reports to SCIEH.

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LABORATORY SURVEILLANCE

Routine laboratory surveillance to SCIEH is based on voluntary reporting by laboratories in Scotland. As such it is subject to all of the biases inherent in any such a surveillance system and reports in most instances are likely to represent an under-estimation of clinical disease. This may be less with VTEC than with some other gastro intestinal infections given the potential clinical severity of the illness. It is still however dependent on the voluntary submission of clinical samples, the laboratory success in isolating the organism and the voluntary reporting to the surveillance system. Any of these can be subject to different pressures and can vary over both time and geography and therefore distort the numbers reported. At best the numbers should be used to indicate trends. Neither infection with VTEC nor the development of HUS is notifiable.

With the laboratory surveillance system the trends for different enteropathogens have varied in recent years. While salmonella has shown a slow steady increase since the mid 1980s, campylobacter has risen consistently and dramatically yet cryptosporidium has if anything fallen since the peak in 1989 (Figure 1).

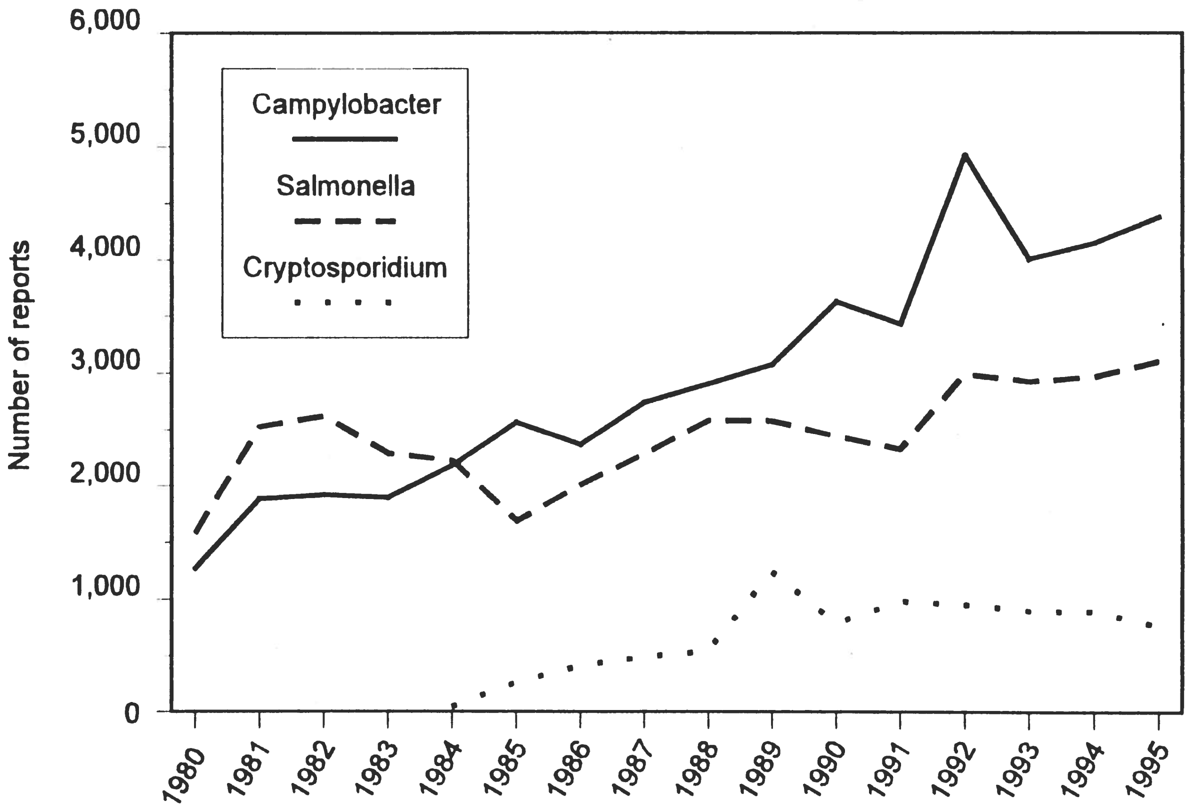

Fig 1. Annual total of gastro-intestinal infections (human laboratory isolates) reported to SCIEH, 1980 - 1995

In contrast reports of VTEC have been steadily increasing, with the exception of a dip in 1992/3, since they were first reported in 1984. At 247 the number of isolates reported in 1995 was slightly higher than the previous highest year - 1994 (Figure 2). However the epidemiology of cases in 1995 was significantly different to the previous year and the number of sporadic cases, ie. non outbreak, rose dramatically from approximately 100 to more than 240.

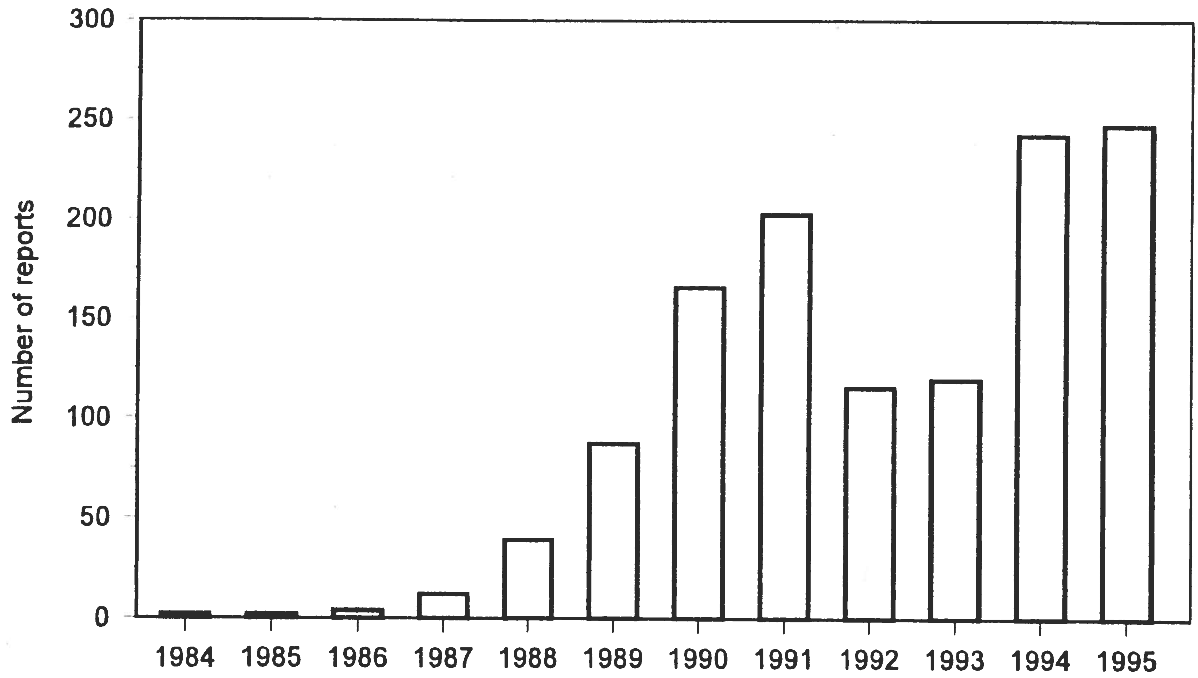

Fig 2. *E.coli* O157 isolates in Scotland, 1984 - 1995

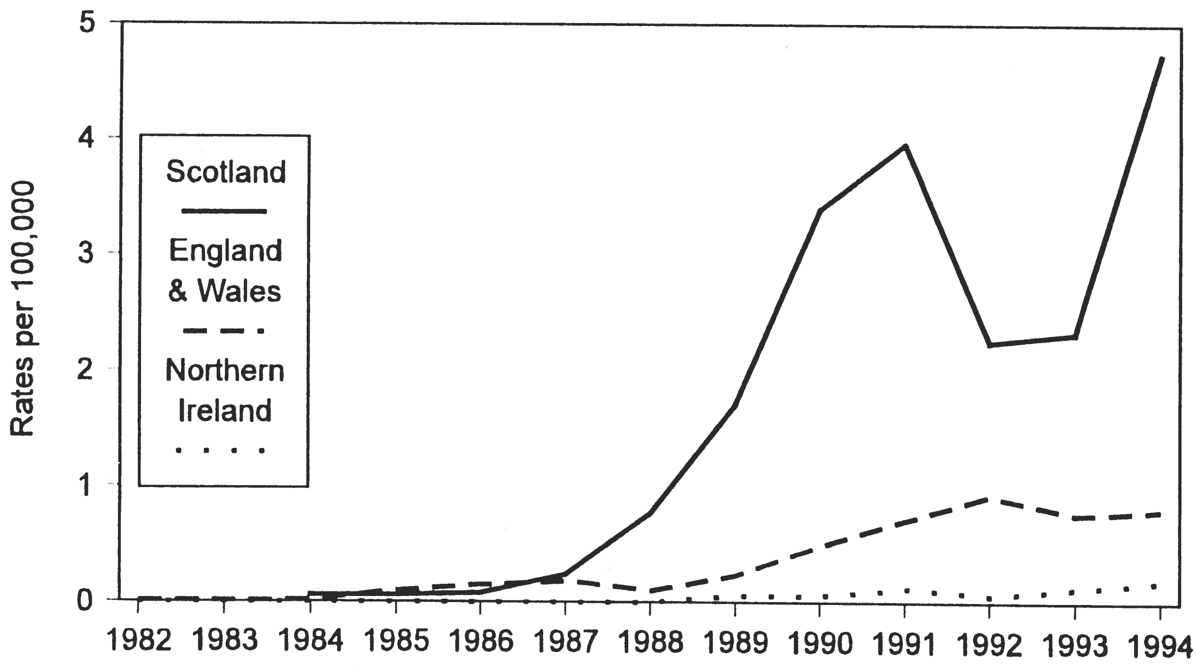

Fig 3. *E.coli* O157 laboratory reports in the UK, 1982 - 1994

When compared with the rest of the UK, Scotland now appears to have a rate some four times greater than England and Wales (Figure 3) (Anon 1995). The reasons for these differences are not clear but appear to be real. For examples Wales has an active ascertainment surveillance system yet has a rate no greater than the rest of England and Wales.

However even within Scotland there is considerable geographical variation, with considerable differences between Health Boards. While the average annual rate for the whole of Scotland from the period 1990-94 was approximately 3.3 per 100,000 this varied from nil for the Shetlands to 9.7 in Grampian (Figure 4).

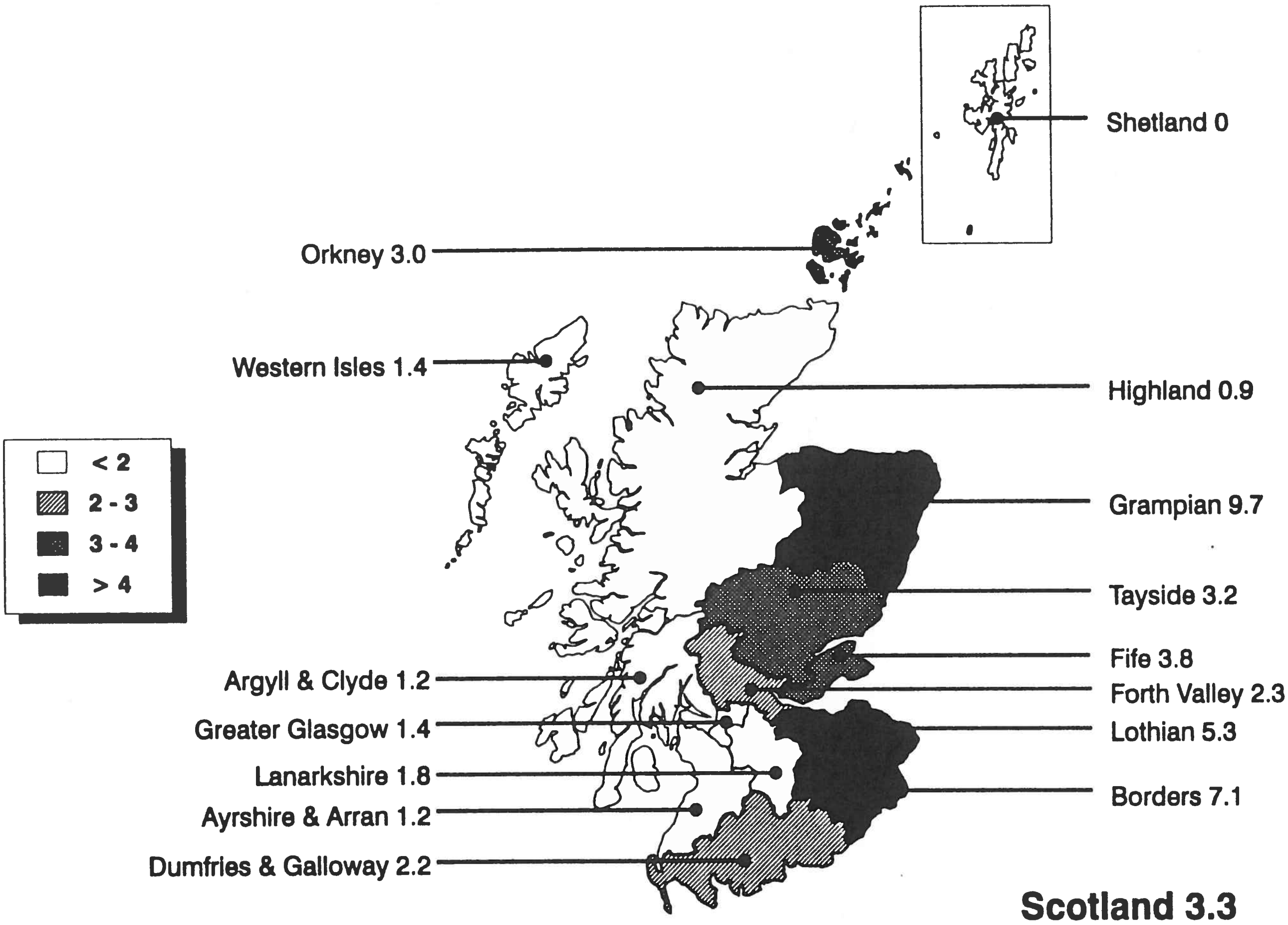

Fig 4. Average annual rates of *E.coli* O157 in Scotland by health board of reporting laboratory, 1990 - 1994 per 100,000 population

In 1995 the differential was even greater - again Grampian had the highest rate of 17.3/100,000 against a national average of 4.8 (Figure 5). It is difficult to account for these geographical differences, which again appear to be real and consistent. With such relatively small numbers rates can be distorted by the cases associated with outbreaks. However in 1995 only one small outbreak was reported yet the distribution of sporadic cases varied dramatically.

As is also the case with other enteric infections such as campylobacter, there is a tendency for an East/West geographical split and also an urban/rural split. It is postulated, but not yet proven, that this may reflect different exposures to for example livestock or untreated water supplies. Further studies are underway to test such hypotheses.

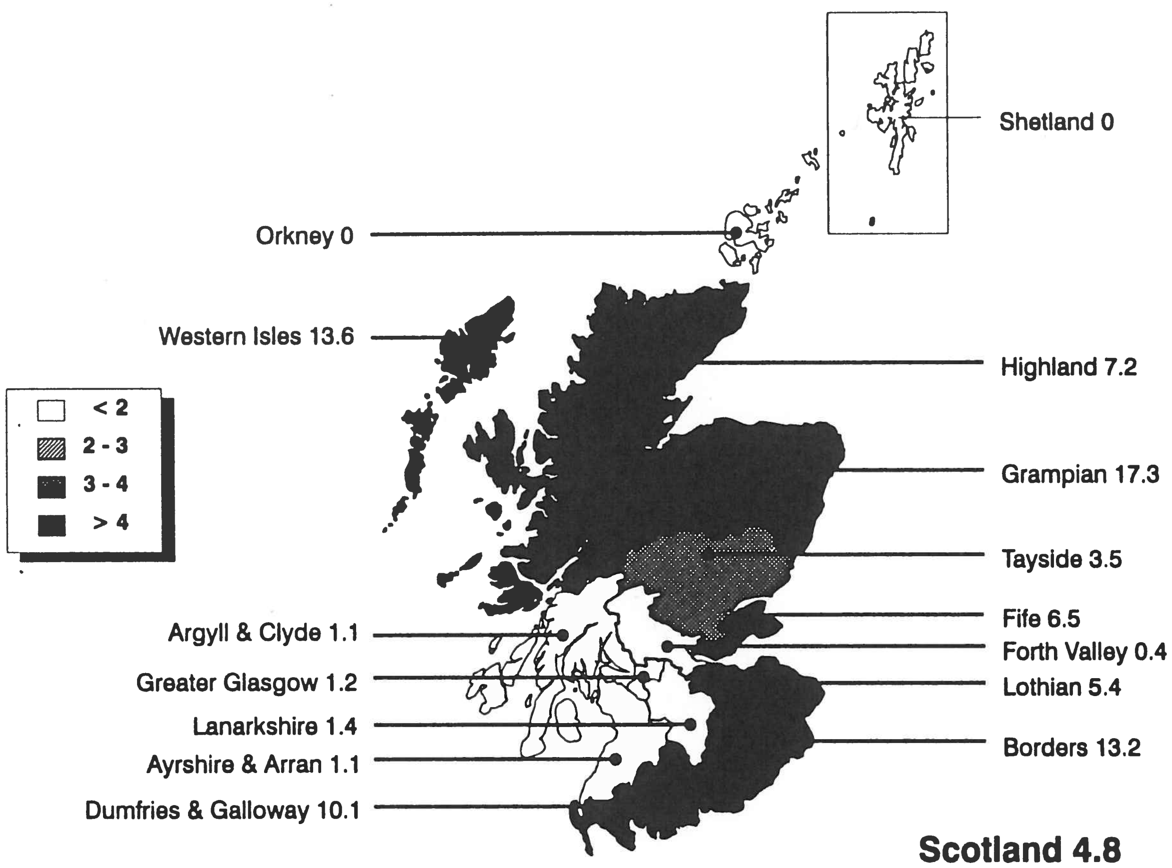

Fig 5. Annual rates of *E.coli* O157 in Scotland
by health board of reporting laboratory, 1995 - per 100,000 population

In the last 4 years it is not clear that there is any consistent seasonal variation (Figure 6). This is in marked contrast with the other potentially food and waterborne pathogens such as salmonella, campylobacter and cryptosporidium which show a very marked seasonal distribution with cases predominantly in the spring and summer months. The apparent peak in early summer of 1994 reflected a single large outbreak of over 100 clinical cases and 69 isolates. In 1995 there was an increase in isolates reported during the autumn and early winter which was attributed to environmental factors associated with the excessively dry summer followed by a very wet autumn. One effect of this was on the quality of untreated usually private water supplies.

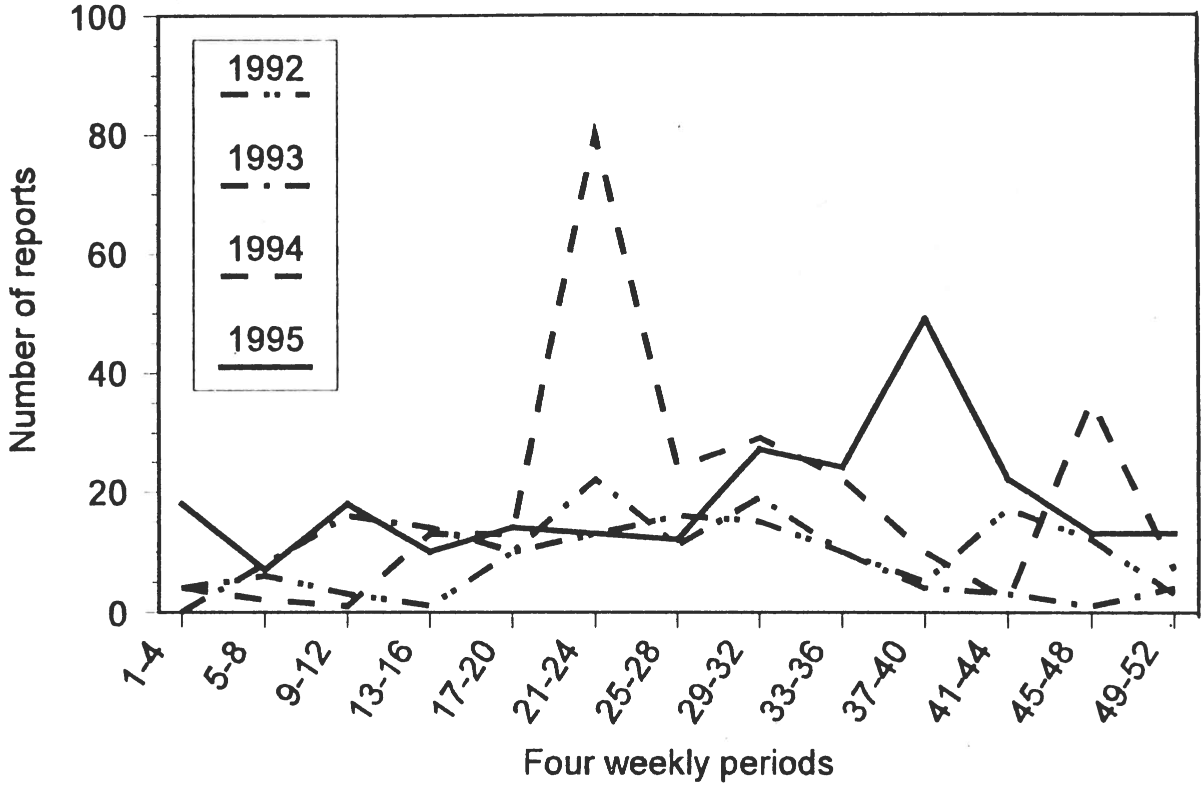

Fig 6. Laboratory reports of *E.coli* O157 isolates to SCIEH, Scotland, 1992 - 95

Since 1989 increasing dependence has been made on Reference Laboratories to further characterise and differentiate the VTEC isolates. Phage typing in particular has been an important epidemiological tool but increasingly differentiation methods such as pulsed field gel electrophoresis allow further strain identification. This has provided invaluable additional epidemiological information and again this demonstrated differences between Scotland and the rest of the UK.

Between 1989 and 1994 phage types 2 and 49 predominated (Figure 7). A similar situation pertained in England and Wales. However in 1995 while phage type 2 continued to be the most common type, phage type 28 emerged as a major type (Figure 8). There was no apparent geographical differences with phage type 28 accounting for some 30% of all typed isolates in most health boards. Interestingly phage type 28 has not been reported in England and Wales emphasising the different geographical nature of this infection. In isolates made from animals phage types 2, 28, 31, 32, 49 and 54 have also been identified, illustrating the potential of this source for human infection.

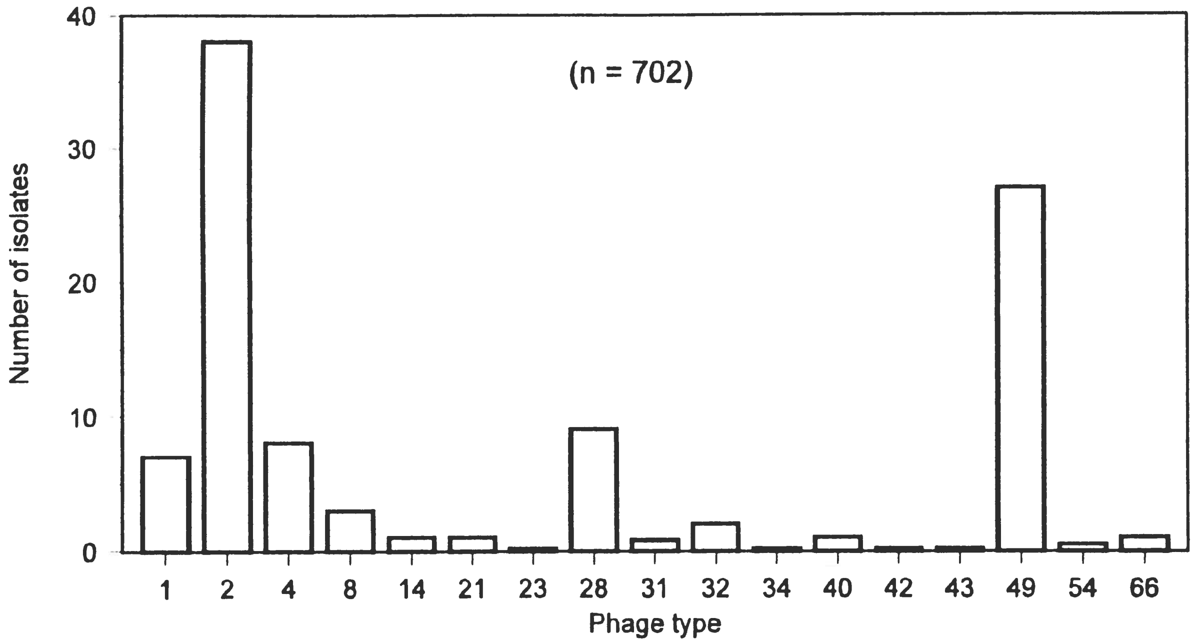

Fig 7. Frequency of phage types of *E.coli* O157 identified, 1989 - 1994

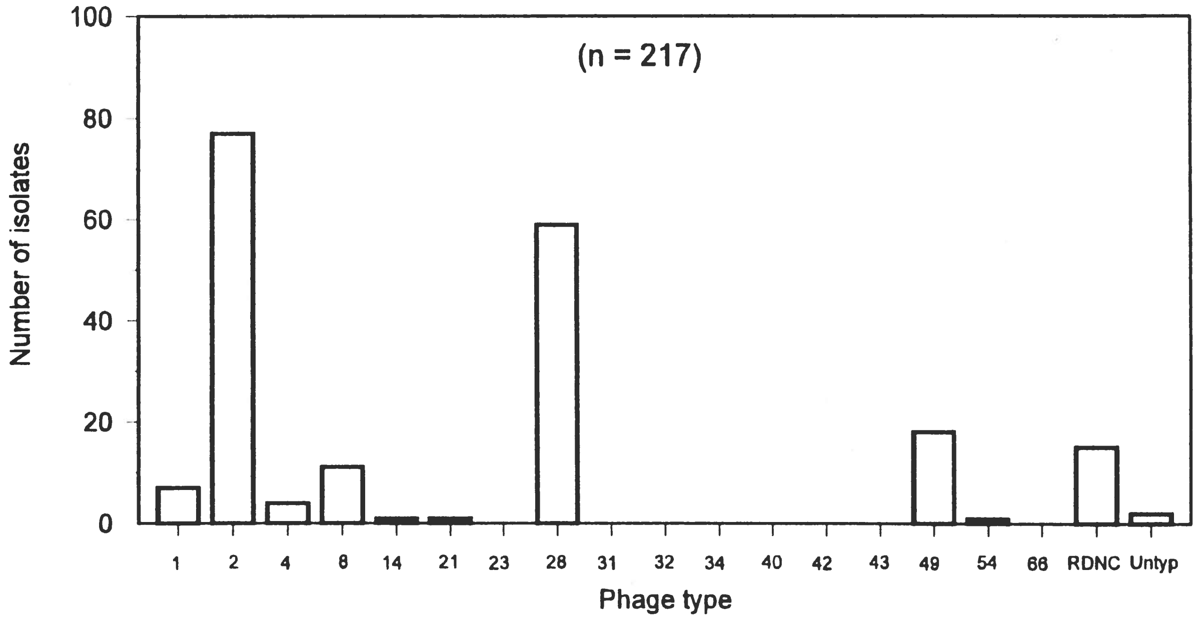

Fig 8. Frequency of phage types of *E.coli* O157 identified, 1995

ANIMAL AND FOOD SURVEILLANCE

One of the strengths of the Scottish Surveillance System has been the ability of the different professional groups to co-operate and this is particularly so with VTEC. While not apparently an animal pathogen there is no doubt that animals form at least part of the reservoir of infection. The Scottish Agricultural College Veterinary Services (SAC) began a research programme in 1992 to examine routine faecal submissions for VTEC. This has demonstrated the presence of the organism in cattle - but not in other species. The majority of isolates were from calves under 2 months (Synge & Hopkins, 1994). In addition SAC have been particularly helpful in investigating cattle contacts of known human cases (Synge et al, 1993), and to date 13 such investigations have resulted in the isolation of strains of VTEC from cattle indistinguishable from the human isolates.

Not surprisingly the farms where identified cattle have been identified are widely scattered throughout the country (Figure 9).

Fig 9. Farms where *E.coli* O157 infected cattle have been identified, 1992 - 1995

SAC are continuing to investigate herds where the organism has been isolated, to look at factors such as faecal excretion, seasonal variation etc. This work will be essential to understand the role of cattle in the epidemiology of human disease. Other ongoing work by MAFF is looking at the presence of VTEC on carcases in abattoirs in the UK including Scotland. Very recently infected sheep have also been identified in the UK, but not yet in Scotland (Chapman, Siddons & Harkin, 1996).

In contrast to the success in isolating VTEC from animals recoveries from human food sources have been few and disappointing. While now frequently isolated from foods in North America only three isolates have been made in Scotland - all associated with human disease.

In three separate outbreaks the suspected vehicle of human infection (milk, cheese and water) has been shown to carry an indistinguishable strain from the human cases. No isolations have been made from meat, despite the epidemiological evidence to suggest that meat, and burgers in particular, is an important vehicle, although such a source has been implicated epidemiologically (Davis & Brogan, 1995).

OUTBREAK SURVEILLANCE

In addition to laboratory surveillance SCIEH also receives reports on outbreaks of infectious disease from all Health Boards usually from the Consultants in Public Health Medicine. These can be part of specific surveillance programmes such as for foodborne disease or ad hoc reports. Analysis of laboratory data often identifies clusters of cases and may be the first indication of such an outbreak.

Outbreaks other than family associated were not apparent until 1989. From 1990 onwards community outbreaks have been reported each year involving foodborne, waterborne, person-to-person, nosocomial and zoonotic spread (Table 2).

Table 2. General community outbreaks of *E.coli* O157 infection, 1990 - 1995

	Type of outbreak	Location	Nos. affected (HUS)	Phage type	Suspected Source
1990	Community	Grampian	4 +	2	Waterborne
	Nursing home	Glasgow	8 (2)	49	Foodborne
	Restaurant	Lothian	16 (4)	49	Foodborne
	Hospital	Lanarkshire	11 (2)	2	Nosocomial
	Nursing home	Edinburgh	5	49	Foodborne
1991	Community	Lothian	5 (2)	2	Foodborne
	Residential homes	Borders	18	1	Meat
	Community	Grampian	10 +	2	Restaurant
	Restaurant	Glasgow	2 +	31	Burgers
1992	Birthday party	Borders	5 (1)	49	Paddling pool
	Hospital	Glasgow	5 +	1	Nosocomial
1993	Birthday party	Lanarkshire	5 (3)	2	Person-to-person
1994	Community	Fife, etc	24 (1)	4	Burger meat
	Community	Lothian	100 + (9)	2	Milk[a]
	Community	Highland, etc	8 (3)	2	Milk
	Community	Lothian, etc	16	28	Burger meat
	Community	Borders	4 (1)	2	Zoonotic
	Community	Grampian	22 (1)	28	Cheese[a]
1995	Community	Fife	5	2	Waterborne

[a]confirmed bacteriologically

Outbreaks identified have emphasised the role of person to person spread from the index case. For example in one psychogeriatric hospital outbreak in which 4 patients died the origin was attributed to food brought in for a patient with nosocomial spread (Kohli et al, 1994). Children's birthday parties appear to be a particular risk and in one incident contamination of a paddling pool was involved (Brewster et al, 1994). Food and waterborne sources were suspected epidemiologically but not confirmed prior to 1994. In one UK-wide outbreak involving a hamburger chain two Scottish cases were identified only by the uncommon biochemical properties of the isolates (Thomas et al, 1993). In other episodes it appeared that cross contamination of food in a restaurant was involved (Marsh et al, 1992).

In some episodes there were several risk factors identified. For example in a farming community involving several different families the risk factors identified included consumption of raw milk, contaminated water supplies, and the use of cattle manure to fertilise vegetables. VTEC, but of a different phage type, were isolated from one dairy cow.

In another unusual outbreak involving four households the only common factor identified was the purchase of vegetables from door to door vendors.

In 1994 five foodborne outbreaks were reported and for the first time isolates were made from two of the suspected foods. These outbreaks accounted for almost 60% of all isolates in that year.

Over a seven week period from early April, a community outbreak affected 11 persons resident in several communities in one Health Board, all of whom were associated as shop-assistants or as customers, with one or other of two butchers' *"shops within shops"* as within a national chain of supermarkets. In addition 13 persons in other districts across central Scotland were concurrently also reported as having been similarly infected. A case-control study demonstrated an association between VTEC infection and the purchase of "burgers" (Davis & Brogan, 1995).

In May an explosive outbreak involving a "heat-treated" milk supply affected over 100 persons, mainly young children from 69 of whom the organism was isolated. Approximately one third of cases required admission to hospital, and nine of these aged 11 months to 11 years developed HUS; one elderly woman developed thrombotic thrombocytopaenic purpura. The use of immunomagnetic bead separation resulted in the recovery of VTEC from several clinical and environmental samples, including several from the processing dairy, which originally had been negative by direct culture (Upton & Coia, 1994). Indistinguishable organisms were isolated from cattle on one farm supplying the dairy.

In early July, VTEC phage type 2, was isolated from seven persons, mainly children, in five geographically scattered families. All households had purchased milk in 1 litre cartons produced by the same dairy. Prior to the onset of illness of the first cases, the dairy had identified and subsequently rectified a fault in the processing of that particular product. In later July, 16 cases of VTEC phage type 28, infection were identified across several districts of east-central Scotland. All of those affected, with two exceptions, lived in and around the city of Edinburgh or had visited Edinburgh Zoo in the week preceding onset of illness. Most had eaten burgers or had purchased burger-type meat from local retail outlets, although further enquiries were unsuccessful in demonstrating a common source.

In November, 22 people were affected in an outbreak (phage type 28), associated with locally produced unpasteurised farm cheese. Organisms indistinguishable from the human isolates were isolated from samples of cheese taken at the point of consumption, although not from cattle investigated on the farm of origin of the cheese. The index case in this outbreak was the cheesemaker and the possibility that this person contaminated the cheese cannot be excluded.

In contrast with 1994 only one community outbreak was reported in 1995. This occurred when sewage effluent contaminated mains water. There were however 30 single household or family outbreaks identified, again emphasising the importance of person to person spread irrespective of the original source of infection.

CONCLUSION

After 13 years some of the epidemiology of VTEC is beginning to become better understood, yet many questions remain unanswered. Person to person spread may ultimately be the most important route - emphasising the importance of personal hygiene, yet the source for the index case must be removed. There is no doubting the role of livestock as reservoirs or indeed direct sources of infection. Considerable work needs to be carried out to describe the epidemiology of the infection in cattle before control methods can be considered if applicable. Food, possibly of animal origin or contaminated by animal by products, is at least part of the explanation. Work still requires to be carried out not only in refining laboratory methodologies but in developing the surveillance systems. As is so often the case the availability of funding will determine the progress made.

In any event Scotland is well placed to take this forward given the size of the problem and the history of interprofessional co-operation in this and other fields.

ACKNOWLEDGEMENTS

The SCIEH is fortunate that it receives the considerable support of all relevant groups in Scotland. The author acknowledges the input from laboratories, whether medical or veterinary, health boards and local authorities without whose support no national surveillance system could exist.

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EPIDEMIOLOGY OF MEAT-BORNE ZOONOSES IN NORWAY

EYSTEIN SKJERVE[1], GEORG KAPPERUD[1,2]

New and re-emerging infectious diseases have increased in humans during the past 20 years and have reached epidemic proportions in several countries. A substantial proportion of all re-emerging infections is related to food. Among the agents involved are *Salmonella*, *Campylobacter*, *Yersinia*, *Escherichia coli* O157:H7, *Listeria*, *Toxoplasma*, and *Cryptosporidium*. The situation has been characterized as a serious problem with substantial economical, political, and public health consequences. Food-borne illness is one of the largest preventable public health problems. Although factors as travelling are of importance for the spread of food-borne infections (Wilson, 1995), there is a clear pattern that most of the problems are linked to the water-borne infections in poorer countries, and to animal-linked infections in the industrialised countries. The reasons for the re-emergence of food-borne infectious diseases are many and complex: Methods of food production, storage, distribution, and preparation are rapidly changing. The international trade in food, animal feed, and live animals expands rapidly with establishment of single markets without trade barriers. More intensive farming and production systems have also contributed to the problem. These changes have brought with them new challenges in food hygiene (Anonymous, 1995). In Norway, several epidemiological investigations have been conducted during the last ten years to elucidate the importance of meat products as a vehicle for *Salmonella*, *Campylobacter*, *Yersinia*, and *Toxoplasma*. This paper presents aspects of the epidemiology of these food-borne infectious diseases in Norway.

Salmonella

Salmonella spp. are the most frequently reported bacterial agents of acute diarrhoeal illness in Norway followed by *Campylobacter* and *Yersinia enterocolitica*. In 1994 the national surveillance system records approximately 1400 bacteriologically verified cases among the 4.3 million Norwegians every year. During the past decade the number of reported cases due to *S. enteritidis* has increased considerably.

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No similar increase has been observed for other *Salmonella* serotypes. In contrast to the situation in most European countries, a large majority (ca. 90%) of the Norwegian cases have acquired the infection abroad. The importance of imported meat as a source of infection was emphasized by a recent case-control study designed to identify risk factors for salmonellosis among patients who contracted the infection in Norway. Preliminary analysis shows that eating poultry and pork products purchased during weekend trips abroad is associated with a statistical risk for salmonellosis (OR=11.3 and OR=5.1, respectively; $P \leq 0.02$). In contrast, no risk was detected for the following food items produced in Norway: poultry, egg, beef, pork, mutton/lamb, game, or minced meat products.

A bacteriological survey comprising 23,149 representative food samples was conducted in 1991. The prevalence of *Salmonella* spp. in Norwegian meat and meat products was estimated to be 0.1%. *Salmonella* was not isolated from 7931 eggs examined in 1994. In 1995, an outbreak of *S. livingstone* infection in poultry flocks was successfully combated; not a single human case was reported. On the other hand, there is an endemic reservoir of *S.* Typhimurium in wild birds. This serovariant is also sporadically encountered in mesenteric lymph nodes from slaughtered pigs.

Campylobacter

Campylobacter jejuni/coli is the second most common bacterial agent of a acute diarrhoeal illness in Norway. The number of culture-confirmed cases recorded by surveillance has increased considerably in recent years: While ca. 600 cases were reported in 1992, the number had risen to ca. 1000 in 1994. About 50% of the patients had acquired the infection abroad. A case-control study conducted in 1989-1990 showed that the following factors were independently associated with an increased risk of acquiring *Campylobacter* infection in Norway: (a) living in a household with a dog (OR=5.19, P=0.029), (b) consumption of meat at a barbecue (OR=4.37, P=0.002), (c) drinking non-disinfected water (OR=3.69, P=0.016), (d) eating poultry which was brought into the house raw (frozen or refrigerated) (OR=3.48, P=0.024), and (e) living in a household with a cat (OR=4.86, P=0.052). When poultry consumption was examined according to country of origin, eating poultry purchased during weekend trips abroad was strongly associated with illness (OR=13.66, P=0.014), whereas consumption of poultry produced in Norway was not (OR=1.33, P=0.41) (Kapperud et al., 1992).

Bacteriological surveys have documented the prevalence of *Campylobacter* in wild and domestic animals and in the environment in Norway. The bacterium is frequently encountered in the avian wildlife fauna, poultry, dogs, cats, pigs, sheep, and in surface water sources. In a study comprising 176 broiler flocks from separate farms, 32 (18%) of the flocks were found to be colonized at slaughter. The following variables were found to be independently associated with an increased risk of *Campylobacter* colonization: (a) feeding the broilers non-disinfected water (OR=3.42, *P*=0.045), (b) tending other poultry prior to entering the broiler house (OR=6.43, *P*=0.007), (c) tending pigs before entering the house (OR=4.86, *P*=0.037), (d) geographic region (OR=2.91, *P*=0.023), (e) season (autumn versus other seasons) (OR=3.43, *P*=0.008). Further analyses indicated that about 53% of the cases of *Campylobacter* colonization could potentially be prevented by proper disinfection of drinking water (Kapperud et al., 1993).

Yersinia enterocolitica

An annual average of approximately 200 culture-confirmed human cases of *Y. enterocolitica* infection is recorded by the surveillance system. In contrast to *Salmonella* and *Campylobacter*, a great majority (90%) of the patients have contracted their *Yersinia* infection in Norway. A case-control study conducted in 1988-1990 identified the following independent risk factors: (a) frequency of consumption of pork products (*P*=0.02), (b) frequency of consumption of sausage (*P*=0.03), and (c) drinking non-disinfected water (*P*=0.01). Patients were also more likely than controls to report a general preference for eating meat prepared raw or rare (*P*=0.01) (Ostroff et al., 1994). The epidemiological findings complement bacteriological surveys documenting common carriage of *Y. enterocolitica* serogroup O:3 in Norwegian pigs. The bacterium was isolated from the oral cavities of between 32 and 83% of pigs at slaughter and from up to 63% of pig carcasses. *Y. enterocolitica* O:3 has also been isolated from between 0.1 and 18% of retail pork products. Using a DNA probe, pathogenic yersiniae were detected in 60% of Norwegian pork products (Nesbakken, 1988; Nesbakken, Gondrosen, & Kapperud, 1985; Nesbakken et al., 1991). A recent serological survey showed that ca. 40% of pig herds may be free from *Yersinia*, and indicated an association between *Yersinia* infection in herds and trade of live animals into the herd (Skjerve et al., manuscript).

E. coli O157:H7

Infections linked to verotoxin producing *E. coli* has only occasionally been observed in Norway, and O157:H7 has not been detected in the cattle population. Recently, 2000 cattle from 200 herds in Norway were found negative for verotoxin producing O157:H7. There were, however, a small number of samples containing *E. coli* harbouring the verotoxin gene, and in two out of 200 herds, animals with *E. coli* O157:H- were found (Wasteson et al., manuscript).

Toxoplasma gondii

A serological screening program conducted in 1991 to 1994 encompassing 37,000 pregnant women from 11 of Norway's 19 counties, showed a seroprevalence of 11% (range 7-14%) (Jenum et al., manuscript). The incidence of primary infection was estimated to 0.18% among susceptible pregnant women. A case-control study identified the following risk factors for maternal *Toxoplasma* infection: (a) eating raw or undercooked minced meat products (OR=4.1, *P*=0.007), (b) eating raw or undercooked mutton (OR=11.4, *P*=0.005), (c) eating raw or undercooked pork (OR=3.4, *P*=0.03), (d) eating unwashed raw vegetables or fruits (OR=2.4, *P*=0.03), (e) cleaning the cat litter tray (OR=5.5, *P*=0.02), and (f) washing the kitchen knife infrequently during preparation of raw meat, before handling another food item (OR=7.3, *P*=0.04) (Kapperud et al., manuscript). By univariate analysis, traveling outside Scandinavia was identified as a significant risk factor, but this variable was not independently associated with infection.

Recent studies on domestic animals complement these epidemiological findings. A serological survey of meat producing mammals in Norway found the highest prevalence of *Toxoplasma* specific antibodies in sheep, where more than 40% of lamb flocks were positive, and 18% of the individual lambs. Only 4.9% of pig herds and 2.5% of individual slaughter pigs were positive. The main risk factors for introducing the parasite in lamb flocks were: (a) close contact with young cat, atypical (close to farm) pasture and (c) altitude >200 meters above sea (Skjerve et al., manuscript).

DISCUSSION

Norwegian meat and meat products seem to constitute a moderate health hazard through the spread of *Yersinia enterocolitica* and *Toxoplasma gondii* infections. The production systems specific for Norway have managed to keep down *Salmonella* in special and partially *Campylobacter* infections to an extent where Norwegian meat seems only to play a marginal role in the epidemiology of these diseases. A high standard of hygiene in the production of poultry and pigs, a strict control of animal feed and an animal husbandry consisting of many spread small units of animals might explain the situation. An important part of this specific epidemiological pattern has been the minimal food import from other countries and a conservative attitude to eating raw or undercooked meats among the population. Whether this situation will remain if the Norwegian food marked becomes more integrated in the European market, also facing the changes in food technology and eating habits, remains to be seen.

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INVITED PAPER

THE ROLE OF THE PUBLIC SECTOR IN CONTROLLING THE EPIDEMIC DISEASES OF LIVESTOCK

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The epidemic diseases of livestock that appear in the Office International des Epizooties (O.I.E.) List A are those 'that have the potential for very serious and rapid spread, irrespective of national borders; which are of serious socioeconomic or public health consequences and which are of major importance in the international trade of animals and animal products. Of the fifteen diseases currently on the list six (foot-and-mouth disease (FMD), swine vesicular disease (SVD), contagious bovine pleuropneumonia (CBPP), classical swine fever (CSF), African swine fever (ASF) and Newcastle disease) have occurred in the territory of the European Union in recent years.

These diseases are costly to eradicate by stamping out particularly when very large livestock units, such as the 500 cows or 1000 sow units found in certain parts of the Union, are involved. The most costly and untractable epidemics in recent years have been the CSF epidemics in Germany and Belgium. One unofficial estimate has put the cost of the recent extensive series of outbreaks in Germany (1993-1995) at 1.5bn D.M. (1.0 bn US$). This figure includes direct and indirect losses in the livestock industry and allied trades (feedstuffs, abattoirs, meat, transport etc) but also includes the costs accruing to the public sector and covering compensation payments, market support and the cost of the control operations. The direct costs to the public sector (control operations and compensation payments) of the 1993 FMD epidemic in Italy (57 herds slaughtered) have been estimated at 4.6M US$ and the 1994 Greek FMD epidemic (95 flocks slaughtered) at 6.1M US$ (Davies and Leslie 1996).

This unsatisfactory state of affairs leads us to ask three questions: What went wrong? why were the epidemics, particularly the CSF epidemics, so costly? and is it right that a substantial part of the losses should be borne by the public purse? These questions lead inevitably to a further, more fundamental question: what is the appropriate public sector responsibility for controlling epidemic diseases, as they occur in European livestock systems at the end of the twentieth century.

What went wrong? The risk factors associated with CSF in pig herds in northern Europe have been described elsewhere (Davies 1994). Some of the outbreaks have been caused by feeding untreated swill containing wild boar meat, or by direct contact between infected wild boar and domestic pigs. Once the infection gains access to the domestic pig population in this way it spreads to widely dispersed units through the long distance transportation of pigs and locally, from farm to farm, by traffic in pigs, farm machinery, supply vehicles and farm workers.

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These processes are illustrated by the events leading to the major CSF epidemic in Lower Saxony in 1993-1994. A small breeding unit on the Franco-German border contracted the infection after the sows were put out in fields adjacent to a forest that was known to contain infected colonies of wild boar. Breeding stock sold to pig units in Baden-Württemburg caused a few small scale outbreaks, but no further losses until weaner pigs purchased by a dealer from a holding incubating undetected disease, were transported to Flanders and Lower Saxony, both areas that contain some of the highest densities of pigs in Europe. In Lower Saxony the infection spread like wild-fire and was only contained after a determined and sustained eradication campaign.

Clearly there were failures on the part of the industry; breeding sows should never have been allowed contact with wild boars, greater care should have been taken in purchasing weaner pigs from areas where there had recently been outbreaks of the disease and finally the local movements of pigs, vehicles and personnel between large fattening units should have been subject to greater discipline. These are failures of preventive medicine.

There were also identifiable failures on the part of the authorities. Some cases were mis-diagnosed although it has to be said that the clinical signs of CSF are so variable and laboratory diagnosis so uncertain that in the circumstances the diagnostic failure rate was remarkably low. There were also failures to control movements, but in some areas movement controls in infected zones were regarded by owners and dealers alike as an unjustifiable restraint on trade.

Why were the epidemics so costly? Although the public sector costs associated with the CSF epidemic in Germany have not been separately estimated they were substantial and probably accounted for a large part of the global 1.5 BN D.M. estimate referred to earlier. The costs fall under three headings.

- the costs of general control actions by the veterinary authorities, police etc.

- the costs of measures on infected premises. These include compensation, cleansing disinfection and associated measures. (These costs, in FMD infected herds in Europe have been estimated at anything between 5000 US$ and 416,000 US$ (1987 values) per herd depending on the size of herd and species involved (Davies 1993).

- the cost of market support. Community Market support measures were employed during the CSF epidemics to purchase slaughter weight pigs from units quarantined within infected zones. The pigs were killed and as there was no market for the meat the carcases destroyed.

These market support costs were a result of the movement restrictions imposed within the Union following outbreaks of CSF (Council directive 80/2217/EEC as amended). Similar restrictions are in force for other List A diseases. All movements of pigs are prohibited within zones of 3 Km radius from the infected premises (protection zone) and 10 Km radius (surveillance zone). Movement controls have played an essential part in the eradication of epidemic diseases of livestock since the 17th century but rapid transport systems and dense livestock populations have made it difficult to maintain these controls for any length of time. In certain communes in Flanders there are up to 9000 pig places per km_2 of agricultural land

and in Germany the density of pig units can be as high as 7.2 units per km_2. Table 1 shows the epidemic control resource implications based on these admittedly extreme densities.

The CSF epidemic in Lower Saxony and the movement zone restrictions associated with it, lasted several months and, involved a large part of the land covering several coalesced 10 km zones. It can be seen that in the absence of any other relief up to 90,000 fat pigs would have to be culled in each zone each week. It is clear that a major epidemic of FMD, CSF or any other rapidly spreading disease in these dense livestock regions would tax the resources of even the best equipped veterinary service.

The role of the public sector? The final question is whether it is right that the substantial costs involved in controlling epidemics should continue to be borne by the public sector and brings into question the role of the public sector in controlling epidemic diseases of livestock.

To understand the development of the present responsibilities of the public sector one must look at the origins of the veterinary services. The British service was founded in 1865 and took over responsibilities for controlling epidemic diseases previously shouldered by local authorities. The method of eradication has changed little since 1714 when an epidemic of Rinderpest was conquered by destroying all infected cattle, disinfecting cow byres, quarantining in-contact herds and controlling movements. Compensation was paid to all who complied with the orders and during the 1745 epidemic cost the authorities £7,000 a month.

The authorities did not appear to question their role in controlling these epidemics although there was some dissent over the policy of stamping out. It is not often that the Exchequer readily accepts such financial responsibilities and when it does it is usually a case of the defence of the realm. The control of epidemics of disease in livestock was regarded as defending an essential national interest, i.e. maintaining the country's food resources that would be vital to the survival of the nation in times of war.

This precept has served us well through two world wars, but it is timely to ask whether it remains valid today. War, if it occurs, will be nasty, brutish but short and unlikely to involve a protracted siege. In times of peace food is plentiful on the world market and it is no longer the case that we must be reliant on food from our own resources. Power and Harris (1973) attempted to measure disruption costs in the distribution sector of the agricultural and food industry during the 1967-68 FMD epidemic in the UK when 2,364 herds were destroyed. They concluded that the epidemic had no significant effect on the British meat market.

The livestock industry at the end of the twentieth century is no longer a resource vital to the national interest, it is an industry like any other subject to the disciplines of the market that should in theory force it to adopt efficient husbandry and trading practices including the controls associated with preventive medicine.

Before we rush to conclude that the public sector must divest itself of responsibility for controlling epidemic diseases of livestock, we should ask whether there is a feasible alternative. The public sector does two things: it regulates the movements of livestock and takes remedial action when disease outbreaks occur and it bears the costs of those actions and protects the industry through compensation payments.

Table 1:

The resources required to maintain 3 and 10 Km radius control zones, assuming densities of 7.2 pig units per Km_2 and 9000 pig places per $Km_{2.}$

	Protection Zone (3 Km radius)	Surveillance Zone (3-10Km radius)
No of pig units (7.2 per $Km_{2.}$)	203	2,057
No of pig places (9000 per $Km_{2.}$)	254,340	2,574,000
Surveillance resources		
(a) Clinical surveillance assuming 5 units/ person/day	40 veterinarians (daily inspection)	400 veterinarians
	6 veterinarians (weekly inspection)	59 veterinarians
(b) Laboratory resources (serological surveillance)		
Assuming 2 rounds: - at Day 1 to identify true primary - at Day 40 to identify secondaries (60 samples per herd)	12,000 samples	123,420 samples
Financial resources		
Market support costs Assuming fat pigs (30 weeks to slaughter)	Weekly cull 8,333 pigs	Weekly cull 83,333 pigs

It is difficult to conceive of a private sector arrangement that will result in effective remedial action although attempts have been made in South America and possibly elsewhere, to get the industry to police movement regulations. The eradication of epidemic disease, particularly FMD (Marangon *et al.* 1994) demands prompt action supported by the rule of law. The case for the public sector to continue with this responsibility is overwhelming.

The present arrangements for bearing the cost of disease eradication are less defensible. The events leading to the CSF epidemic in Germany were largely due to poor preventive medicine practices - the feeding of untreated swill, the purchase of pigs from unaccredited sources through a network of dealers and the failure to maintain sanitary barriers, such as all in - all out systems on the farm. They suggest that under the present arrangements, certain segments of the livestock industry pay little heed to preventive medicine, knowing that they will be compensated if and when disease occurs. Would they pay more heed if they knew that they would not be compensated. The answer is probably the same as it would have been in 1714; some would tighten up their sanitary regimes, whilst others would continue to gamble on making a quick profit from buying cheap stock and further would conceal the disease if and when it occurred. The case for maintaining compensation payments is irrefutable.

Nevertheless, the present arrangements do little or nothing to force the livestock industry to accept the disciplines of preventive medicine. Is there a feasible alternative that would? A system to be effective would have to encourage the good and penalise the errant stockowner. The farmer who employs the principles of preventive medicine in his business is a low risk for all diseases spread by direct contact whilst the farmer who does not is a bad risk. This risk assessment points to some form of insurance system.

Insurance systems are based on risk and for them to be effective they must identify and quantify the relevant risk factors. The main risk factors affecting the spread of diseases such as CSF are well known, but are worth repeating.

- the purchase of stock from sources of known health status, without passage through markets or dealers premises.

- the maintenance of sanitary barriers on the farm.

- the employment of all in - all out systems that allow for proper disinfection.

- the siting of units so that they are not easily contaminated by neighbours.

It is possible to conceive of a universal livestock insurance system based on these factors in which all licensed animal keepers paid a premium and the premium varied according to their preventive medicine status. The receipts would be held in a trust fund to pay the costs (including compensation) of an epidemic.

It might be said that such a system would impose a further cost on a long suffering industry and would add another bureaucratic control. If the scheme was successful in persuading errant stockholders to mend their ways the costs of epidemic disease, to the industry and to the public purse, would be reduced. There may be a case for questioning the premium payment system but I venture to suggest that controls imposed directly on stock owners who are clearly responsible for the state of their holdings will be more effective than the controls presently imposed, ineffectively on the movement of stock.

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OPEN SESSION

A HEALTH PROFILE OF SWISS DAIRY COWS

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INTRODUCTION

Before disease control programmes can be developed and implemented, base-line information on the incidence of disease, the costs incurred as a result of particular diseases and possible risk factors associated with their occurrence must be obtained. Such information on endemic disease problems is not currently available in Switzerland. In other countries health and productivity profiles, as recommended and described by Morris (1991), have been established. For selected examples concerning the dairy industry see: Dohoo et al., (1982/1983), Bendixen et al. (1986), Emanuelson (1988) and Kaneene and Hurd (1990).

The concept of animal health and productivity profiles has been adopted in this study aimed at 1) investigating incidence of disease in Swiss dairy cows, 2) estimating cost of disease and 3) identifying possible risk factors for common diseases of dairy cattle.

MATERIAL AND METHODS

With the help of the Swiss Federal Office of Statistics a random sample of 284 dairy farms was selected from a total of approximately 60,000 dairy farms in Switzerland. The sample was stratified by herd size and geographic location. The farmers were contacted by mail and asked to participate. Finally, 113 (42%) of the farms were enrolled in the study on a contract basis (for detailed description of farm recruitment see: Stärk et al., 1994).

During a period of 15 months (May 1993 - July 1994) special recording sheets were used by farmers and their vets to record health-related events. All health-related events were coded using an hierarchical system which allowed for different levels of detail in regard to the specificity of diagnosis (for example, Code 110 = Calving disorders not otherwise specified, 111 = Dystocia, 112 = Uterine torsion, 113 = Caesarean section, 114 = Embryotomy, 115 = Stillbirth and 119 = other calving disorders). A written case definition for each code was provided. A total of 89 disease codes were used. For the analysis reported here, different types of diseases were summarised in broad categories (Table 1). For each case, the cost of veterinary services and drugs was recorded, in addition to the period during which treatment with antibiotics prevented sale of the milk for human consumption. Recording sheets were returned to the investigators every second week.

Farms were regularly visited by either of the two study veterinarians. During visits, farm management data were recorded using a set of questionnaires. Blood and faeces were also collected for a range of laboratory analyses. The first three months of the study were considered as a training time and all data recorded during this period were excluded from the analysis.

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TABLE. 1: Disease categories

Category	Diseases
Reproductive disorders	Non-cycling, endometritis, ovarian cyst, other ovarian dysfunction, early abortion or absorption, other disease of the reproductive tract
Diseases of the udder	Acute mastitis, subclinical/chronic mastitis, injury of the udder, decreased milk flow (without injury), pathological edema, skin disease, other disease
Lameness	Sole ulcer, panaritium, laminitis or limax, diseases of the claw pad, other diseases of the claw, arthritis/tendinitis, limb injuries, other diseases of the musculo-skeletal system, other lameness
Puerperal disorders	Calving injuries, placental retention, milk fever, other puerperal disorders
Metabolic disorders	Hypomagnesaemia, ketosis, liver disorders, other metabolic disorders
Calving disorders	Dystocia, uterine torsion, cesarean section, embryotomy, stillbirth, other calving problems
Diseases of the digestive tract	Diarrhea, foreign body, abomasal diseases, other diseases of the forestomach, anorexia, diseases of the oral cavity, displaced appendix, colic due to various reasons, other diseases of the digestive tract

Two measures of disease incidence were used. For calving and puerperal disorders, cumulative incidence (CI) was calculated (Kleinbaum et al., 1982). CI is the measure of choice in dynamic populations, such as dairy herds, if disease occurrence is associated with an event and the period of risk is restricted to a short time following an event. All first recordings of calving and puerperal disorders were used in the analysis, but secondary and tertiary visits linked to the same event were excluded. CI is expressed per 100 calving events.

For all other disease categories incidence density (ID) was calculated (Kleinbaum et al., 1982). ID is the preferable measure when disease occurrence is not restricted to a defined period of time, but is continuously present. Animals which experienced multiple events of the same type during the study period would therefore be counted more than once. In order to calculate the time at risk when more than one episode of disease was possible, an animal diagnosed as diseased was considered as treated and immediately recovered. The denominator was then the sum of the observation periods of all individuals. This approach avoids the need to define recovery periods (Bendixen, 1987). A somewhat different approach was used for reproductive disorders. For each cow the first occurrence of a reproductive problem was included, as subsequent events of the same category were not considered independent observations. Also the time at risk was limited to the period between the previous calving or abortion and the first recording of a reproductive problem or, alternatively if no event occurred, the last insemination date. ID is expressed per 100 animal-years.

The costs incurred as a result of disease included the costs for drugs; veterinary services (including follow-up visits); and costs associated with milk withholding periods. The milk withholding period was multiplied with the average amount of milk produced by a cow per lactation day (1994: 5110 kg per standard lactation of 305 days = 16.75 kg/d; Swiss Milk Statistics, 1994) and the average price a farmer was paid per kilogram (1994: 0.9 SFr.[3]). Indirect losses due to reduced production, earlier culling or less clearly defined opportunity costs were not estimated.

Serum was collected from each cow during farm visits in May/June, 1993. These samples were individually analysed. If at least one animal reacted seropositively, the farm was considered to be infected. In September/October, 1993, faecal samples were collected from all cows. Up to 5 faecal samples from animals from the same farm were pooled for parasitological analysis. If one of these faecal pools provided positive results, the farm was considered infected. Parasitology results are not available for individual cows.

RESULTS

Characteristics of the study farms are listed in Table 2. Herd size, geographical distribution and breed distribution were compared with figures from a total farm census, and it was concluded that the farm cohort was representative of the source population of Swiss dairy farms appropriately (Stärk et al., 1994).

During the study period, a total of 2,262 cows were monitored; this corresponded to a total time at risk of 634,972 cow-days or 1,739.6 cow-years. For reproductive disorders, the total time at risk was 179,685 cow-days or 492.3 cow-years. The breed distribution of the cows was: Simmental, Red Holstein and their crossbreeds 47%, Swiss Brown 41% and Holstein 11% (remaining 1% local breeds).

The average age of cows on January 1, 1994 was 5.4 years. During the observation period, 577 cows were added to the cohort and 517 cows were removed for the following reasons: slaughter due to infertility (26%), slaughter due to other reasons such as age (20%), slaughter due to insufficient milk production (17%), slaughter due to udder diseases (10%), emergency slaughter or sudden death (4%) and not further specified culling reasons (4%). The average age at slaughter was 6.0 years. A number of cows (19%) were sold for breeding or milk production.

The average age at first calving was 956 days (Standard deviation (SD)=133 days) and the average time between calving events 387 days (SD=62). Summary statistics of incidence measures by disease categories are listed in Table 3(a).

[3] 1 SFr. = 0.556 £ (Zurich, 14.1.1996)

TABLE. 2: Descriptive statistics of study farms

	Mean	SD	Median	Range
Number of cows	15.5	6.1	15	5-40
Annual milk quota (kg)	68,900	33,453	65,000	0-171,300
Percentage of total income originating from farm (%)	93.1	19.3	100	10-100
Percentage of farm income from milk production (%)	69.1	20.6	70	33-100
Number of persons tending the cows	2.5	1.0	2	1-10

TABLE. 3(a): Incidence measures by disease category, expressed as incidence density (ID) per 100 animal-years or as cumulative incidence (CI) per 100 calvings

Disease category	Mean of ID[a]	Median of ID[a]	95% C.I.[d] of the Median[a]
Reproductive disorders	152.2	117.3	91.7-151.8
Diseases of the udder	40.5	35.7	30.8-43.0
Lameness	16.4	10.0	5.9-13.6
Puerperal disorders	11.7 [b]	10.0[c]	7.7-11.1[c]
Metabolic disorders	11.6	9.7	7.1-12.2
Calving disorders	8.9 [b]	6.7[c]	5.0-9.1[c]
Diseases of the digestive tract	7.2	0.0	0.0-3.5

[a] calculated on a farm level (n=113); [b] Mean of cumulative incidence; [c] Median of cumulative incidence
[d] C.I. = confidence interval

During the one year study period every farmer spent on average 97.6 SFr. per cow-year for disease related services such as veterinary visits and drugs. He/she additionally lost 46.4 SFr. per cow year for milk that could not be sold because of antibiotic treatments. The average total disease-related costs per cow-year was thus 144.0 SFr.

The top 5 most frequently diagnosed diseases were acute mastitis (374 cases), anoestrus (289 cases), subclinical or chronic mastitis (218 cases), endometritis (182 cases), and placental retention (175 cases). Crude cost estimates per disease category are shown in Table 3(b).

TABLE. 3(b): Estimated costs by disease category

Disease category	Cases	Mean costs per case (SFr.)	Mean costs per cow-year (SFr.)
Reproductive disorders	646	93.35	122.84
Diseases of the udder	727	152.86	63.88
Metabolic disorders	235	140.08	18.92
Lameness	277	112.47	17.91
Puerperal Disorders	212	111.64	23.90
Calving disorders	154	108.58	9.35
Diseases of the digestive tract	100	117.44	6.74

Furthermore farmers spent 10.1 SFr. per cow-year for preventive treatments. Most of these treatments (79.6%) were performed by the farmers without veterinary assistance. An overview of preventive treatments and their costs are presented in Table 4. The total health expenditure for a farm was calculated from treatment and prevention and was on average 154.1 SFr. per cow-year.

TABLE. 4: Preventive treatments

Category	Cases	% performed by farmer	Mean costs per case (SFr.)	Mean costs per cow-year (SFr.)
Claw trimming[a]	1,571	68.7	3.24	2.93
Drying-off with antibiotic treatment	777	99.6	14.48	6.47
Antiparasitic treatment	87	100.0	3.07	0.15
Various preventive treatments[b]	51	72.5	21.35	0.63

[a]only preventive trimmings

[b]Vaccinations, prevention against metabolic and puerperal disorders, de-horning

A total of 1,635 serum samples were collected and analysed. Table 5 shows the results of laboratory analyses for selected bacterial, viral and parasitic diseases.

On average, farmers spent 15 minutes a week recording data. All participating farmers were given regular progress reports and a detailed report with the study results at the end of the survey. Farmers were also invited to participate in information seminars which were organised throughout the country in which results of the study were presented and explained. During the last farm visit, farmers were asked about their attitude towards similar projects in the future: Eighty-two percent were willing to participate in future study, while 15% made their decision dependent of the study design. In upcoming studies, 59% of the farmers would prefer to be financially compensated while 35% may participate without compensation, and 4% were sufficiently interested to continue in a similar study without any payment.

DISCUSSION

As in any field study, data quality was an important issue in this project. As farmers are not trained to diagnose diseases, permanent monitoring and discussion of the recording process were essential. The initial training period of three months allowed farmers to become familiar with the coding system. Data for treatment and service costs related to particular events were more difficult to obtain as they had to be provided by the herd veterinarian. Laboratory costs were poorly recorded and, thus, excluded from the analysis. The co-operation and perceived interest of practising veterinarians were not always optimal, and it may be important to encourage this group before commencing further studies. Consequently, the study was not very sensitive with respect to cost estimation. Furthermore, the capability to record hidden losses related to disease (reduced productivity, additional labour for the farmer, premature culling or reduced value of sold cows) was limited. Cost estimates for the prevention of disease may also be underreported as expenses not specifically related to an individual cow, for example solution for teat dipping, were not recorded, and the proportion of preventable costs was not assessed. Yet, this information is important for understanding the relevance of monetary figures. In this respect, the data from this study are clearly not detailed enough and more elaborated accounting systems as suggested by McInerney and Turner (1989) are necessary.

TABLE. 5: Seroprevalence of infectious disease and prevalence of parasites

Disease	Animals			Farms		
	Number	Prevalence	95%CI	Number	Prevalence	95%CI
Viral diseases						
BVD	1635	71.8	(69.6,74.0)	113	99.1	([a])
IBR	1663	0.1	([a])	113	0.9	([a])
EBL	1663	0.0	([a])	113	0.0	([a])
Bacterial diseases						
Leptospira hardjo	1663	24.9	(22.8,27.0)	113	77.0	(69.2,84.8)
Q fever	1663	13.1	(11.5,14.7)	113	61.9	(53.0,70.8)
Paratuberculosis	1663	5.8	(4.7,6.9)	113	46.0	(36.8,55.2)
Brucellosis	1663	0.0	([a])	113	0.0	([a])
Parasitology						
Gastrointestinal strongylosis	n.a. [b]	n.a.	n.a.	113	63.7	(54.8,72.6)
Trematodes[c]	n.a.	n.a.	n.a.	113	8.8	(3.6,14.0)
Cestodes[d]	n.a.	n.a.	n.a.	113	8.0	(3.0,13.0)
Protozoa[e]	n.a.	n.a.	n.a.	113	71.7	(63.4,80.0)

BVD = bovine virus diarrhoea; IBR = infectious bovine rhinotracheitis; EBL = enzootic bovine leucosis. 95%CI = 95 percent confidence interval

[a] Confidence intervals could not be calculated, because: p x N<=5 or (1-p) x N<=5 (Kleinbaum et al., 1982). [b] no individual samples analysed [c] *Dicrocoelium sp.*; [d] *Moniezia sp.*; [e] *Coccidia*

One of the challenges of the study was the recording of individual animal health data. Although this was time consuming, it helped provide accurate and representative estimates for the incidence of disease. The key requirement for this approach was individual animal identification. All farms used ear tags for that purpose. Small herd sizes also helped detailed data recording for individual cows.

In analysing this data, assumptions were made with respect to the nature of each disease category. In all disease categories, except for the category of 'reproductive disorders', repeated events of the same type in the same animal were considered independent. This assumption was based on the biological plausibility that, over a year, an animal could have more than one incident of the same disease in a given category. With respect to reproductive disorders, it was recognised during data collection that it was difficult for farmers and sometimes veterinarians to assign the clinical signs to a single diagnosis code. In some cases, different diagnoses were recorded within a short time period for the same animal. Therefore, it was decided to consider only the first of these diagnoses.

For the calculation of disease incidence densities, animals diagnosed as diseased in one disease category were considered treated and recovered at the same point in time and therefore immediately became at risk for a new occurrence of disease events of the same category. This assumption was necessary because no valid definitions for the recovery periods for different diseases were readily available. And even if they had been available they would not have been applicable to broad disease categories including diseases with different recovery periods. Furthermore, if recovery periods had been used, incident cases of other diseases within the same category during that interval would have been missed. However, more specific calculations are possible when limiting the number of cases to more specifically defined health problems, where recovery periods can be estimated. The definition of the time at risk for ID is known to be a possible source of bias (Bendixen, 1987). Thus, the approach used in this study may have resulted in an underestimation of the true incidence by overestimating the time at risk. For reproductive disorders, the time at risk was limited to the calving-to-conception period. Consequently, the ID for reproductive disorders is higher when compared with other diseases, although the number of cases occurring was moderate. It is important to remember these assumptions when interpreting the results or when comparing them with results from other studies.

Despite these technical problems, the information provided by this profile is considered extremely valuable as such estimates were previously unavailable. It was shown that it is possible to establish a health profile using a random sample of farms, provided there is sufficient emphasis on farmer motivation and training. Personal contact and feedback of results were also important in order to prevent farms from leaving the study.

This survey has provided a complex data set, which remains to be completely analysed. This article gives a limited selection of the information provided by the study. The base-line information is important to both the veterinary profession and the dairy industry, and, as such, the objectives of the study have been achieved. Similar follow-up projects, and projects in different sectors such as swine production are planned for the future.

ACKNOWLEDGMENTS

The authors are grateful to the farmers for their co-operation and to all staff of the Veterinary Faculty Laboratories for the analysis of the samples. The project was financed by the Swiss Federal Veterinary Office and kindly supported by BIOKEMA S.A., Crissier-Lausanne, Switzerland.

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INTERROGATION OF A HOSPITAL DATABASE:

FROM DATA TO DECISION SUPPORT

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In the fields of both human and veterinary medicine, the realm of ancillary clinical testing has developed enormously in recent years (Kaneko, 1988). The estimated yearly cost of such testing in the United States is over 27 billion dollars (The New York Times, 1987). Results of clinical biochemistry tests are now readily available to clinicians through the innovation of analysers designed for the practice environment, e.g. 'Vettest 8008' (Little et al., 1992). However, interpretation of these results remains rather subjective, with evaluation based on the experience of the individual clinician, who may refer to means and ranges on the premise that the data are normally distributed, an assumption which may not always be correct.

For the last 18 years, results of clinical biochemistry tests have been stored within the University of Glasgow Veterinary School (GUVS) Hospital database. The database of over 60,000 records from more than 25,000 animals represents a rich source of information (Little et al., 1994). Clinicopathological data have also been stored. Interrogation of these data has revealed significant associations between disease and different biochemical analytes.

MATERIALS AND METHODS

The GUVS hospital data recording system is a computerised DataFlex system comprising of a number of databases containing signalment, clinical, biochemical, haematological and pathological information. Using the 'query' facility to interrogate the databases, equine cases which had plasma biochemistry testing carried out as part of their investigation were identified. The biochemistry results for these cases were extracted from the database and imported into a Microsoft Excel spreadsheet. For each horse with at least one panel of biochemistry results, the clinical diagnosis associated with that hospital visit was also retrieved from the database.

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During the period covered by the study, a variety of biochemical analyte tests had been employed. The array of analytes to be measured from any one plasma sample was not always chosen on a selective basis. For the equine cases a total of 20 analytes were investigated, namely, urea, sodium, potassium, chloride, calcium, magnesium, phosphate, creatinine, albumin, globulin, total protein, bilirubin, glucose, creatinine phosphokinase (CPK), alkaline phosphatase (SAP), gamma-glutalmyl transferase (GGT), cholesterol, LDH, amylase and aspartate amino-transferase (AST). Only the first panel of plasma biochemistry results for each case was used for this study. During the period covered by the study, different instruments had been employed for measuring various biochemical analytes and, therefore, it was necessary to separate the biochemistry results into two appropriate groups. For each biochemical analyte, a percentile analysis was performed, treating each group separately. Percentile analysis was performed to provide an indication of the spread of the biochemical concentrations obtained, i.e. whether the distribution was normal or skewed.

Using the results of the percentile analysis, the biochemistry values and the corresponding clinical diagnoses were grouped into ten appropriate intervals. At this stage, the absolute value for any biochemistry analyte result was no longer considered and the results achieved from the differing assay techniques, standardised by the analysis, were combined. The five most commonly occurring diagnoses within each of the ten biochemical percentile intervals were then determined. Bayesian methods were used to attach probabilities to these diagnoses. Using rules of probability, a ratio was derived. This ratio revealed information about the value of measuring biochemical analytes in particular diseases. The appropriate probabilities and ratios were calculated for each diagnosis, within each percentile band, for each biochemical analyte.

The results from the interrogation of the GUVS hospital database were then used to form the basis of a biochemical decision support system. Using Knowledge Garden's KPWin++ development environment (Knowledge Garden Inc., USA), C++ code was produced and compiled to yield a PC-based Windows application.

RESULTS

The retrospective study involved 740 equine cases which had received biochemistry testing. Table 1 shows the frequency with which plasma biochemistry samples were taken. The majority (51%) of cases had only one biochemistry sample taken, upon which a number of different biochemical analytes were measured. However, the range of the number of biochemistry samples taken from an individual animal was 1-34. The mean number of biochemistry samples taken per horse was 2.7. Only the first biochemistry sample was included for analysis in this study. Table 2 shows the number of times each biochemical analyte was measured. For a short period covered by the study, different instruments had been used to achieve the biochemistry results. These results were separated, and form 'group 2' in table 2. From the combined results ('total cases'), it can be seen that urea and alkaline phosphatase, then creatinine, were measured most often, with individual analyte selection reducing in frequency down to amylase, which was measured least often.

Table 1. Biochemistry sample frequency

No. of samples taken per horse	Frequency
1	371
2	133
3	84
4	46
5	26
6	19
7	18
8	9
9	3
10	7
10+	24

Table 2. Analyte frequency

Biochemical analyte	Total cases	Group 1	Group 2
Urea	677	596	81
Alkaline phosphatase	677	594	83
Creatinine	661	580	81
Total protein	656	573	83
Albumin	654	572	82
Globulin	652	570	82
AST	647	572	75
Sodium	637	562	75
Potassium	636	560	76
Chloride	631	556	75
Bilirubin	627	551	76
Calcium	607	530	77
Phosphate	599	523	76
Magnesium	577	504	73
Cholesterol	396	359	37
GGT	282	240	42
CPK	247	218	29
Sugar	107	99	8
LDH	22	22	0
Amylase	8	8	0

In order to ascertain the distribution of the analyte concentrations obtained, a histogram was produced for each biochemical analyte. Figure 1 demonstrates that the distribution of the albumin results was not normal, but was skewed with a tail to the left. Many of the analyte results in this unwell equine referral population did not display normal distributions. Table 3 gives an indication of the type of results achieved from the percentile analysis of some of the analytes, namely - sodium, potassium, chloride, calcium and magnesium. The results for group 1 only are depicted.

Fig. 1 Distribution of albumin results

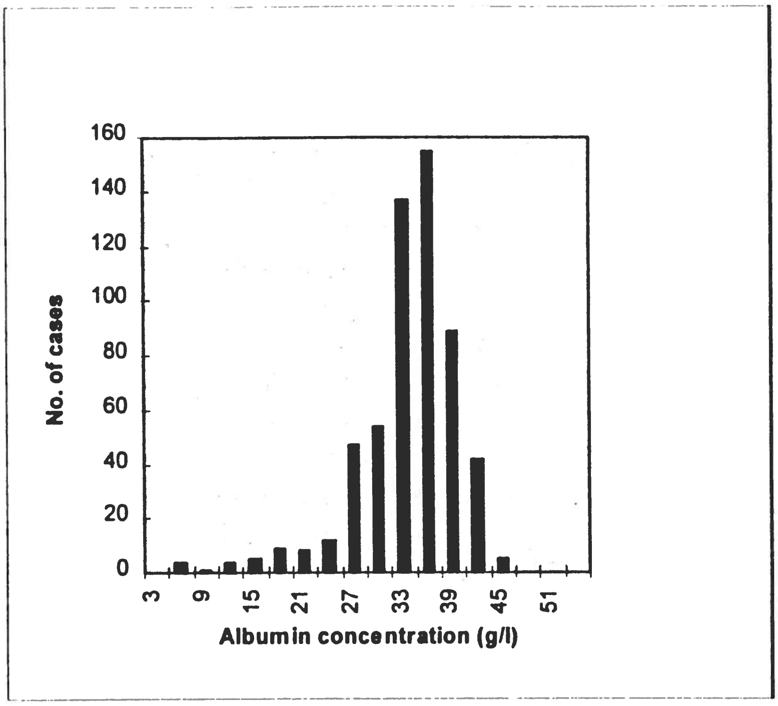

Table 3. Example of percentile results

	Min.	5%	25%	50%	75%	95%	Max.
Sodium	104	130	135	137	139	142	159
Potassium	1.30	2.50	3.20	3.60	4.00	4.91	10.50
Chloride	49	89	96	98	101	105	124
Calcium	0.590	2.404	2.810	2.950	3.090	3.236	3.570
Magnesium	0.250	0.460	0.590	0.660	0.720	0.817	3.170

The 'Biochemical Thermometer' is the decision support system which has been derived from the results of the interrogation of GUVS Hospital database. The design of the system is based on a thermometer analogy, a concept familiar to potential users. The delivery of the information provides a visual representation of a patient's metabolic state. Using the percentile system, the user is made aware of how the specific values of the analytes measured compare to all those seen at GUVS. To simplify the concept further, the starring system described by Little et al. (1994) has been adopted. If the measured value lies in the top 1% of all GUVS cases, it is allocated four stars, if the measured value lies in the top 5%, then it is allocated three stars, and so on. To further aid in diagnosis support, the 'Biochemical Thermometer' reveals the most likely GUVS diagnoses, corresponding to the measured value. Information on confirmatory tests, expected clinical signs and management of these conditions is then obtainable via hypertext links to a multimedia knowledgebase.

DISCUSSION

As both human and veterinary medicines advance, so too do clients' expectations. Clients may demand a diagnosis, explanations of disease processes and treatment, and a prognosis. These criteria, realistically, may never be met for every case, but as an ever increasing range of ancillary clinical tests becomes readily available to the clinician, there is a greater chance of reaching a diagnosis. In this respect, an extensive array of biochemistry tests is now available to most practising veterinary clinicians (Douglas & Eckersall, 1985, Little et al., 1994). Currently, the standard guide to interpretation of biochemical analytes is based on a 'normal reference range'. This is achieved by calculating the mean and standard deviation of biochemistry results, for each individual analyte, from a sample of a healthy population of the species in question. The range is determined by the mean plus or minus two standard deviations (mean ± 2sd) (Farver, 1989, Pickrell et al., 1974, Okotie-Eboh et al., 1992). However, experienced clinicians realise that a value from an unwell animal may be just outside the reference range, or may be well outside the reference range, and it is the clinician's experience which guides him/her as to how to interpret that result (Kerr, 1989). As shown by Little et al. (1994) with respect to the dog, and in this study, with respect to the horse, the distribution of results of biochemical analytes in an unwell referral population often is not normal. Application of statistical methods which assume normally distributed data therefore may be misleading. The 'normal reference range' thus provides limited information about an unwell population. Mee (1995) highlighted a further pitfall of the 'normal reference range'. An international study was conducted to compare the different reference ranges and methods employed by various laboratories. There was enormous variation within biochemical analytes with respect to 'normal reference ranges'. One possible explanation could be that absolute biochemistry results vary depending on the method of analysis used, and the individual instruments within that technique. However, Mee's study (1995) found that a proportion of the laboratories surveyed had not set a reference range using their own instruments, but had opted for a range which had been set by an unrelated laboratory. This practice could lead to confusion in the interpretation of case results.

Percentile analysis does not assume normally distributed data. Percentile values have been used previously in clinical medicine to establish reference limits (Farver, 1989, Okotie-Eboh et al., 1992, Pickrell et al., 1974). Expression of biochemistry results in percentile form negates the confusion which may arise when comparing biochemical analytes which have very different concentrations or units. A further advantage is the ability to compare directly results achieved from different types of biochemical analysis technique. Expression of biochemistry results thus becomes simplified in that absolute values need no longer be considered. For example, a value of urea of 2mmol/l in an equine case may be meaningless to those inexperienced in biochemical interpretation, or to those who, although experienced in small animal biochemistry, may be unsure of the implications in an equine case. By employing the percentile analysis technique, it may be ascertained that the value of 2mmol/l lies within the bottom 1% of equine urea results from the hospital database. This indicates whether a value is abnormal, in this case low, and also the degree of abnormality.

In this study, to assist further with decision support, the appropriate diagnoses were correlated with the biochemical results. Thus, a clinician may appreciate whether a value is abnormal, the degree of abnormality, and the most likely associated diagnoses. In the study hospital, using the same example (urea concentration of 2mmol/l), the most likely diagnosis was hepatopathy. From pathophysiological knowledge, this is certainly a possible diagnosis, but here it was derived from clinical data. Furthermore, application of Bayesian methods allows clinicians to determine how many times more likely a particular diagnosis is, than before any information had been available. Similar conditional probability techniques are applied in the legal system (Good, 1995).

Before analysis of the hospital biochemistry data was undertaken, a number of issues were addressed. Many unwell animals which are investigated at GUVS require more than one biochemistry test. This may be for several reasons including monitoring a case over time or revisitation to the Veterinary Hospital for an unrelated reason. In an attempt to remove this source of potential bias, only the first biochemistry sample result for each case was included in the study. A further potential complication was variation between results when different biochemical analysis techniques were employed. It is recognised that when different techniques are used to perform a biochemistry assay, results can vary slightly (Carlson, 1990, Farver, 1989). During the study period, two different methods of biochemical analysis were used. For this reason, the data were divided into two appropriate groups, and then standardised by the percentile analysis.

The diagnoses used in the study were often tentative clinical diagnoses. In many cases, a definitive diagnosis was not reached. This is a very important consideration, because it highlights the possible circular argument which may follow: If a diagnosis was made with the aid of clinical biochemistry results, then the biochemistry results will reflect that diagnosis. It may be argued, therefore, that some of the results are based on expert opinion, as opposed to being completely data derived. It must also be appreciated that the population under study is an unwell referral population and it should be regarded as a biased population with respect to the frequency of certain diseases (Slater & Boothe 1995). Therefore, the results from this study, although valuable, may not be applied directly to the general practice situation. However, with the computerisation of many veterinary practices, a 'general practice database' may be established in the future. The statistical techniques described in this study could then be similarly applied to a general practice population, with potentially important results.

The study has realised the ability to convert raw data into useful knowledge. This knowledge is conveyed via the 'Biochemical Thermometer' which provides a means of biochemical decision support in the veterinary domain. Through a user-friendly computer interface, clinicians are able to determine objectively whether a measured analyte value is abnormal, the degree of abnormality, and the most likely associated clinical diagnoses. The system is based on clinical data and as such provides knowledge that improves the ability to diagnose and manage disease.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the staff of the equine division of the Department of Veterinary Clinical Studies, University of Glasgow, particularly Professor Sandy Love, for provision of clinical expertise and diagnoses, and the staff of the Clinical Biochemistry laboratory who were responsible for the production of the biochemistry results. Thanks are also due to David Irvine, who aided in the extraction of the data, and to Professor Max Murray for guidance and support during the project. The Scottish Higher Education Funding Council 'New Initiative' Fund and The Home of Rest for Horses have provided financial support for this project.

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QUANTIFYING RISK FACTORS FOR COCCIDIOSIS IN BROILERS USING DATA OF A VETERINARY POULTRY PRACTICE

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Coccidiosis in broilers is a world wide problem. Coccidiosis is caused by protozoa of the species *Eimeria* spp. Effects of coccidiosis are a decreased body weight gain and a worsened feed to gain ratio, causing substantial economic losses (Braunius, 1987). In The Netherlands, these losses are estimated at about 20 million Dutch Guilders each year (1 Dutch Guilder is approximately 0.40 British Pound). It has been shown that eradication is not possible with an anticoccidial program, due to increasing problems with drug resistance (Chapman, 1993). Use of vaccination programs for commercial broiler meat production is not to be expected in the near future (Lillehoj and Trout, 1993). So, other ways of controlling the disease must be found. To develop an optimal prevention program, knowledge about circumstances on farms is essential, enabling the identification of factors which significantly influence the probability of the disease. In the present study, factors associated with coccidiosis were quantified using data which covered a 3-yr period and involved 177 farms, which is 11.4% of all broiler farms in the Netherlands. This study was done within the framework of building a simulation model for infection with *Eimeria* in broilers (Henken *et al.*, 1994a,b). The central point in this simulation model is the population dynamics of the parasite *E. acervulina* and effects of the parasite on broiler production. Effects of factors influencing both the parasite and host population and their interaction have to be implemented in the model. Therefore, data from broiler farms were analysed to find and/or quantify these factors.

MATERIAL AND METHODS

General

In The Netherlands, broilers are raised from hatching (± 40 g) to slaughter (± 1850 g) in a flock cycle of about 6 weeks, with a feed to gain ratio of about 1.89 (IKC, 1994).

Data

A database from a veterinary poultry practice was used. The program "DOP" (i.e. a dutch abbreviation of: Veterinary Research of Poultry) was intentionally designed to make use of up-to-date information to improve poultry flock health. A relational database was developed based on two one-to-many relations, client/house and house/period. The database contains, for each flock, information concerning anamnesis, clinical signs, therapy, vaccination, etc. which is collected by the visiting veterinarian (at flock level) and information collected in the laboratory

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(at animal level). The latter information regards results of dissections, bacteriology, sensitivity tests and serology. Data used in the present study were collected from January 1992 until January 1995. The primary data were derived from the database. Additional information was collected by means of a questionnaire, filled out by the veterinarians. The data covered a 3-yr period and involved 177 farms with 2.6 houses on average. There are 4774 flocks in total in the database. This means that flocks are clustered within farms.

Definition of coccidiosis cases and variables

Once a week a varying number of chicks per flock (3 to 21) was examined for the presence of oocysts in intestinal scrapings. Scrapings were examined microscopically (magnification 10x10). Ten fields of vision were counted, thereafter averaged and given the label "control" if no oocysts were found. For each species *Eimeria* found, the label "minor", "moderate" or "serious", was given in case oocysts were present (see Table 1). Since each *Eimeria* species is found on a specified site in the intestines it is easy to distinguish between species. For each species a flock was considered to be a coccidiosis case if at least one bird showed microscopical presence of oocysts during the flock cycle, irrespective of the degree of infection. Flocks in which no birds with microscopical presence of oocysts were found were regarded to be controls. Table 2 shows the variables taken into account.

Table 1. Classification of degree of infection with 3 *Eimeria* species.

E.acervulina		
control:		: no oocysts
case:	minor	: =< 1 group of oocysts or =<20 oocysts in case of singular oocysts
	moderate	: 2-3 groups of oocysts or 21-50 oocysts in case of singular oocysts
	serious	: > 3 groups of oocysts or >50 oocysts in case of singular oocysts
E.maxima		
control:		: no oocysts
case:	minor	: =< 10 oocysts
	moderate	: 11-20 oocysts
	serious	: > 20 oocysts
E.tenella		
control:		: no oocysts
case:	minor	: =< 10 oocysts
	moderate	: 11-30 oocysts
	serious	: > 30 oocysts

Statistical modelling

Data analysis was done according to the case-control type of research (See Thrusfield, 1995). Coccidiosis positive flocks were compared with coccidiosis negative flocks in relation to exposure to potential risk or preventive factors. Four species of *Eimeria* were observed, *E. acervulina*, *tenella*, *maxima* and *brunetti*. However, the last species was only found in 0.1% (n=3) of all flocks and was therefore omitted from the statistical analysis. First, univariate logistic regression was performed for each variable using presence/absence of each *Eimeria* species separately (PROC LOGISTIC: SAS, 1989). Variables associated with coccidiosis positive flocks at a 0.25 P-level, were used in multivariate logistic regression (for method see Hosmer and Lemeshow, 1989). In the multivariate model, variables with a $P>0.10$ were excluded from the model, one by one (first the least significant, etc.). This resulted in a model containing variables related to presence of coccidiosis. In this model all possible two-way interactions were tested for significance. Additionally, a NESTED procedure (Goelema *et al.*, 1991) was performed. This was done because flocks on the same farm are clustered and therefore probably not independent.

Table 2. Variables

Variable with regard to:	Variable[1]
Coccidiosis control measures	In case of serious coccidiosis
	In case of often occurrence of coccidiosis
Medication	Antibiotics
	Anticoccidials
	Vitamins
	Others
Result of dissections other than coccidiosis	Locomotory disorders
	Intestinal disorders (other than coccidiosis)
	Pulmonary disorders
	Other diseases
Chick house	Feeding system
	Feeding scheme
	Drinking water system
	Control of drinking water with respect to contamination
	Heating system
	Ventilation system
	Age of house
	Floor condition
	Climate regulation
	Number of broilers per m^2
	Measures to keep litter dry
Risk on introduction of diseases	Number of visits of veterinarian
	Regular weighing of chicks during flock cycle
	Working personnel
	Admittance of visitors
	Use of overalls by visitors
	Hygienical status
Environment	Region
	Other farm animals on the farm
	Other broilers in neighbourhood
	Presence of vermin
	Destruction of vermin
	Type of farmyard
Farmer characteristics	Age of farmer
	Educational level of farmer
Others	Feed mill
	Hatchery
	Breed of chickens
	Quality of faeces

[1]Most variables were categorical.

RESULTS

In 63% of all flocks one or more *Eimeria* species were found (Table 3). *E. acervulina* infection, alone or along with other species occurred in 55% of all flocks. For *E. tenella* and *E. maxima* these figures were respectively 31% and 10%. Since *E. acervulina* was the most prevalent one, the analysis was first concentrated on this species. Analysis of *E. maxima* and *E. tenella* infection will be presented later.

As yet, in logistic regression the following variables were significantly associated with *Eimeria acervulina* positive flocks: variables related to feeding system, heating system, feed mill, other diseases (locomotion, intestines, pulmonary system), curative medicine application against coccidiosis or other diseases, presence of other farm animals, age and education of farmer, quality of faeces, hygienical status, use of overalls by the visitors, number of visits by veterinarian and type of farmyard (Table 4).

A significant farm-effect due to clustering of flocks within a farm, was absent for *E. acervulina*.

Table 3. Number of positive flocks infected with *Eimeria* spp.

	nr. of case-flocks	% of all case-flocks
E.acervulina	1407	46.5%
E.acervulina + *E.tenella*	836	27.6%
E.tenella	314	10.4%
E.acervulina + *E.tenella* + *E.maxima*	282	9.3%
E.acervulina + *E.maxima*	88	2.9%
E.tenella + *E.maxima*	56	1.8%
E.maxima	45	1.5%
total positive flocks	3028 (63%)	100%
total negative flocks	1746 (37%)	
total flocks	4774	

DISCUSSION

Results of this study showed that *E. acervulina* is the most prevalent *Eimeria* species in broilers. This was also found in other studies (Braunius, 1987; Voeten, 1987).

This study was done within the framework of building a simulation model for infection with *Eimeria* in broilers (Henken *et al.*, 1994a,b). One important aspect in modelling is guiding and stimulating experimental and field work. Models help with finding gaps in knowledge or might form the framework for decision making (Scott and Smith, 1994). As in any infectious disease, in coccidiosis in broilers two populations are involved: population of the parasite *Eimeria* and the population of hosts, the broilers. It is important to have knowledge about both populations and about factors that influence these populations as well as the host-parasite interactions, including the influence of control measures. When these factors are quantified it should be possible to implement it in a simulation model describing the host-parasite relation and its effects on host productivity.

Table 4. Explanatory variables and their Odds Ratios with their 95% confidence interval of the NESTED multivariate model for *Eimeria acervulina*.

Variable related to:	Variable	Category	Odds Ratio	95%.-CI
Medication:	Coccidiosis	No	Reference	-
		Yes	3.2	1.7-6.0
	Others	No	Reference	-
		Yes	1.4	1.2-1.7
	Vitamins	No	Reference	-
		Yes	1.2	1.1-1.5
Dissections disorders:	Locomotory	No	Reference	-
		Yes	1.6	1.2-2.2
	Intestinal	No	Reference	-
		Yes	1.7	0.9-3.0[b]
	Pulmonary	No	Reference	-
		Yes	1.7	1.3-2.2
Chick house:	Feeding system	Hanging tubes	Reference	-
		Chain feeder	2.0	1.5-2.7
		Feeding pipeline	4.5	1.5-14.2
	Heating system	Tank-gas	Reference	-
		Gas infra red heater	1.1	0.7-1.5
		Central heating	1.6	0.8-2.9
		Radiant heater	456.6	13.1-15911
		Tank-oil	1.38	0.9-2.1
Risk on introduction:	Number of visits of vet.	Continuous parameter	1.12	1.0-1.3[b]
	Working personnel	No	Reference	-
		Yes	1.6	1.0-2.5[b]
	Admittance of visitors	Just Veterinarian	Reference	-
		Advisor	1.5	1.1-2.1
		Others	0.9	0.3-2.3
	Use of overalls	Yes	Reference	-
	by visitors	No	4.6	2.3-9.4
	Hygienical status	Good	Reference	-
	(vet's opinion)	Not good	1.9	1.0-3.8[b]
Environment:	Other farm business	No	Reference	-
		Horticulture etc.	0.9	0.7-1.3
		Other farm animals	1.7	1.2-2.4
	Presence of vermin	No	Reference	-
		Yes	0.4	0.3-0.6
	Type of farmyard	Pavement	Reference	-
		No paving	2.3	1.3-4.1
Farmer characteristics:	Age of farmer	20-30 year	0.5	0.4-0.8
		30-40 year	Reference	-
		>40	0.5	0.3-0.7
	Educational level farmer	Not related to farming	Reference	
		Related to farming	1.8	1.4-2.4
Others:	Feed mill	1[a]	1.8	1.1-2.8
		2	1.9	1.2-3.0
		3	Reference	-
		4	1.8	1.2-2.7
		Others	1.1	0.7-1.6
	Quality of faeces	Normal	Reference	-
		Changeably	1.2	0.9-1.7
		Wet	4.5	1.7-11.5

[a]since these data were confidential just numerical codes were used
[b]only significant at P<0.10 level

As with simulation modelling, epidemiological modelling can indicate needs for experimental work, especially, since it is difficult to demonstrate causality in a case-control study. Rothman (1986) defined cause of a disease as: an event, condition, or characteristic that plays an essential role in producing an occurrence of the disease. For example, in this study, how is the significant risk on coccidiosis due to the presence of other diseases (locomotory, intestinal as well as pulmonary disorders) explained in terms of causality? Is coccidiosis more likely to occur when another disease is present, or are the other diseases more likely to occur due to infection with *Eimeria*? Many experiments have been done to show the relation between *Eimeria* and *Salmonella* (Takimoto *et al.*, 1984; Qin *et al.*, 1995; Tellez *et al.*, 1994), however the relation with other diseases is unknown. Since coccidial species are present world wide in poultry farms it is important to know about their relations to other diseases.

The results of the study show an enhanced risk on coccidiosis due to environmental and management factors which increase the risk of introducing contamination (no use of overalls by visitors, type of farmyard which is difficult to clean, bad hygienical status, working personnel who might be working on other farms, presence of other animals on the farm, type of feeding and drinking system which is more difficult to clean). Most of these are already considered risk factors, however now they are quantified and could be implemented in a simulation model more accurately.

Unexplainable or 'strange' associations might be due to random error (especially if a large amount of factors are screened), confounding or imperfect biological knowledge. Therefore, the subsequent step should be to reveal the causal mechanisms by experimental work.

ACKNOWLEDGEMENTS

The authors would like to thank all veterinarians of the Veterinary Poultry Practice "Southern Netherlands" for their help with the questionnaire and Leo Littel for making the data available from the data base "DOP".

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EPIDEMIOLOGY IN VETERINARY PRACTICE REVISITED

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The textbook "Epidemiology in Veterinary Practice" (Schwabe, Riemann, & Franti, 1977) provided the first comprehensive description of simple as well as advanced epidemiological tools applicable to promoting the health of animal populations. Principles for herd health management were also addressed. An important message in the book was that a herd health management process in fact should be indistinguishable from a research process (page 247). Two decades later, it is relevant to ask: Are we now able to apply proper epidemiological tools in veterinary practice to utilise available data? Are we able to apply basic research principles to support herd health management?

An approach to apply advanced epidemiological methods at all levels in a typical Danish veterinary dairy cattle practice setting will be outlined in the following paper. This approach is the product of interactive collaboration between several practising veterinarians and the author over a period of ten years. An attempt will be made to define and address herd health management problems from the farmer's, the veterinary practitioner's, and the scientist's points of views. Examples of epidemiological tools for application at animal, herd, and veterinary practice levels will be provided.

THE CONTEXT

Currently, there are approximately 700,000 dairy cows in around 13,000 dairy herds in Denmark. The median herd size is around 55 cows. The number of herds are expected to be well below 10,000 by the year 2000 while the number of cows are expected to remain constant. Virtually all dairy farms have only cattle and are family enterprises. There is rarely more than one hired hand.

A Danish practising veterinarian usually operates together with 1 to 6 partners and 1 to 3 assisting veterinarians. Usually the technical staff is comprised of 1 to 3 people. Most practices are mixed but the majority of the larger practices derive a considerable part of their income from cattle and swine. A practice typically serves from 40 to 150 cattle herds.

Individual cattle treatments still comprise a major part of the workload in cattle practice because lay use of drugs is strictly regulated. Only a minor part of Danish cattle herds receive

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regular herd health visits from a veterinarian. Such visits primarily focus on reproduction and mastitis. Very few veterinarians work purely as dairy herd health consultants.

A nationwide dairy herd improvement association (DHIA) serves about 85% of cows and 75% of herds and handles all the typical DHIA data (e.g. milk production, reproduction, and SCC). Most of the herds keep individual animal records of all treatments with labelled drugs. This process of record keeping became mandatory in June 1995. These health data are filed in one central database together with the DHIA data. The practising veterinarian has access to all these data from the herds. Several organisations and individuals provide tools for data analysis and monitoring. This paper is one of the results of research activities involving visits by the author to veterinary practices and their client herds in an attempt to mimic the practice situation and, thereby, identify herd health management problems relevant to both veterinarians and scientists.

DECISION PROBLEMS IN HERD HEALTH MANAGEMENT

Published descriptions of herd health management systems typically focus on the needs for monitoring and estimation of associations among variables which provide information for decision support systems (e.g. resource allocation, optimisation of culling and cost benefit analyses). That is, the purely quantitative aspects of data analysis (statistics, epidemiology, and economics). Our research related to herd health management conducted in collaboration with practising veterinarians supports the view that these quantitative aspects are very important. However, the needs for addressing more qualitative aspects of inference and subsequent decision making at animal, farm and veterinary practice levels have become clear.

The limitations of quantitative methods in epidemiology have also been pointed out by Meek (1991). He defines the term health promotion as "the combination of educational, organisational, economic, and environmental support conducive to health". Applying this definition, a successful herd health management system should be seen as a health promotion concept which explicitly and simultaneously addresses the needs of the animals (well-being), the farmer (well-being and economic health), and the veterinary practice (well-being, partner relations, and economic health).

Qualitative aspects appear especially important in addressing two problems related to herd health management. 1) Statistical analysis of observational data cannot alone provide valid estimates of causal relations. Consequently, other types of information are needed as input to decision support systems. 2) New goals and values become more and more important in animal production (e.g. animal and human well-being, value related production goals, and sustainability). Such concepts appear to be difficult to handle directly with traditional quantitative methods. These two problems will be elaborated in the following section and some potential solutions will be suggested.

CAUSAL INFERENCE

Greenland (1990) discusses the problems of causal inference related to epidemiology although those problems appear to be the same in any situation where decisions must be made. Basically, Greenland claims that it is impossible to "estimate a causal effect" directly from observational data. For instance, the regression estimate from a linear regression model can only validly be interpreted as a causal effect when the study units are randomised. In addition, the validity of most multivariable epidemiological models is questionable for several other reasons: Cows are usually culled for both health and production reasons. High milk production may cause increased disease risk. Often health care is provided according to production potential, and criteria for health care and culling may change over time due to quota constraints (feed-back mechanisms) and from herd to herd. Such complex processes are virtually impossible to describe with objective data at a larger scale and just as difficult to model validly and precisely.

Often these problems are not even addressed in published studies of the health-production complex in dairy production (and other dynamic populations). To address such problems, the investigator (the scientist or the veterinary practitioner) would at least have to specify time aspects, numerous interaction terms, herd effects, and interaction between herd and risk factors. Specification of such models would dramatically increase the complexity of the resulting estimates and make interpretation (and publication?) difficult. In addition, the model selection process is highly problematic. Forward or backward selection and significance levels are major examples of factors that influence the specification of the final model (e.g. Vaarst & Enevoldsen, 1996).

Consequently, multivariable or multivariate statistical models of observational data should be regarded as purely descriptive. However, such explorative analyses are very useful to investigate the structure of complex data sets. By applying several different analytic approaches based on different conceptual points of views, more facets of the data structure will be revealed (Ducrot et al. 1996). Then qualitative evaluations of the data structure or pattern of associations will maybe reveal important aspects of causation. This final step should be called epidemiological modelling in contrast to statistical modelling. It is, however, very difficult to imagine a statistical model which justifies interpretation of regression estimates from observational data with a general statement such as, for example, "the effect of mastitis on milk production was 2.5 kg per day". A more valid statement resulting from such an analysis would be that "this particular combination of descriptor variables is associated with 2.5 kg less milk than ...".

The randomisation requirement is fulfilled and most of the aforementioned problems are resolved in a typical experiment (e.g. a typical factorial feeding experiment in a research station). However, such trials often require very controlled conditions and health problems usually are multifactorial with different effects of risk factors in different environments (herds). Therefore, the external validity of the experimentally derived effect estimates may be extremely poor. Schwabe et al. (1977) suggest a means of overcoming this problem through an evolutionary operation system (EVOP) in which trials are conducted within herds. This would assure high degrees of both internal and external validity. Such an approach apparently is not widely applied in herd health management. An EVOP approach would be practically feasible as demonstrated by Jensen (1994) who described a nested experiment where both herd and veterinary practice were randomly assigned to experimental "treatment". A difficulty arises in that numerous important real life problems cannot be exposed to randomisation for obvious reasons (e.g., painful diseases and human related socio-economic problems). Consequently, the investigator (scientist or practitioner) has to use observational data. However, causation can be established as numerous examples in veterinary medicine show. The investigation of the BSE-problem is a remarkable recent example (Wilesmith, 1991). One major characteristic of such a successful investigation of causation from observational data could be that the problem should be addressed with several methods and seen from several points of view. Thus, it would be highly unlikely that the investigator would ever be able to set up one single analytic procedure which automatically provided estimates that could be used directly as valid and precise input for a decision support system. Thorough knowledge of the subject matter and epidemiologic insight from the user would still be necessary. This would make "population medicine" very similar to "individual animal medicine". Epidemiological modelling might more precisely be called a diagnostic process to indicate the qualitative and holistic aspects of the analysis. Similarly, predictions and decision support systems could be called prognoses.

This long list of difficulties related to quantitative (epidemiologic) analyses could give the impression that these approaches are not useful at all. This impression is not true. The scientific challenge is to combine the quantitative and qualitative parts of an analysis, including a herd health management situation. The following section provides suggestions on how to increase the trustworthiness of quantitative analyses in herd health management by incorporating qualitative knowledge obtained by the practising veterinarian and the farmer.

AN ANIMAL LEVEL EXAMPLE

A major objective of dairy herd health management is the estimation of the effect of disease on the production of milk (by far the most important dairy herd output), meat and live cattle, both quantitatively (kg) and qualitatively (e.g. SCC in milk and meat classification). Such estimates are crucial for comparing the relevance of alternative disease control strategies.

For the aforementioned reasons, the relations between disease and milk production are difficult to estimate validly and precisely for a particular farm where the information is going to be used for decision support. These problems have been addressed through a within herd and within test day approach (Enevoldsen et al. 1995) conducted as follows: (1) Cows without any health problems are identified. (2) Milk production records from these cows are analysed separately for each test day using multiple regression analysis. Parity and stage of lactation within parity (first and later) are independent terms. (3) The resulting "healthy cow estimates" are used to estimate the expected milk yield for all cows, including the non-healthy cows. This estimated milk yield is then assumed to represent the milk yield of a cow, also non-healthy ones, at any given point in time given she was healthy. (4) The difference between actual and expected milk production is calculated while taking into account a cow effect. (5) These differences ("milk production losses") are presented graphically for each cow together with all other events encountered by the cow (e.g. calving, disease treatment, SCC, and culling. Milk production records with "significant" deviations from expected are automatically pointed out. The data presentation can be tailored by means of the HerdView PC-program (Thysen & Enevoldsen, 1996; currently available free of charge on the Internet).

The objective of this combined graphical presentation of production and health related events is to support discussions between farmer and veterinarian at regular herd visits. The visualisation of the estimate of disease effects on production at the cow level serves to validate the estimates. The farmer and the veterinarian can discuss sequences of events for a sample of cows. If the farmer disagrees with some of the estimates, he can challenge the calculations or the data and have them verified. The procedure also highlights cows with exceptionally low production. Such cows often suffer from chronic disorders or disease events which have not been treated or recorded. Finally, and maybe most importantly, this qualitative evaluation of individual cow "cases" allows causes of disease and production loss to be revealed. For example, insufficient hoof care leading to a severe sole ulcer or insufficient follow-up to dystocia leading to septic metritis.

A HERD LEVEL EXAMPLE

A dairy herd is an open population which is strongly influenced by the states of the individual animals (e.g. pregnancy and health) and the herd (e.g. milk quota and herd size constraints). This complexity means that it is difficult to evaluate the short and long term effects of a management change which may be relevant to disease control. An approach has been developed to support such evaluations (Enevoldsen et al., 1995). The major objectives of the approach are to 1) reveal the dynamics of health and production within each herd, 2) produce herd specific input to a dynamic, stochastic, and mechanistic simulation model of the herd (SIMHERD), and 3) assess future production at various assumptions.

Firstly, the results of the animal level analyses are summarised to provide herd level parameters related to milk production potential, production variability, reproduction efficiency, and health. Secondly, the results from phase one are combined with data obtained from herd visits providing information about production strategies (e.g. milk quota management and replacement policy) and options for management and other changes that may promote health or profitability of production. Thirdly, all available information is utilised to create input files for the simulation model. Fourthly, simulation is used to assess the variability and differences in production and economics of relevant alternative production strategies in the herd (simulation experiments). Finally, the analytic results are presented to and discussed with the farmer. This should in turn lead to new questions and hypotheses and, hopefully, initiate an iterative analytic process.

The simulations begin with a comprehensive description of each animal in the herd at a distinct cut-off day, say the last test day in the herd. Based on this initial herd and herd level parameters such as pregnancy rates and the rate of involuntary culling, the states of each individual animal would be predicted over time. That is, the approach would allow the user to visualise what would be expected to happen to each individual animal in the future, given various assumptions determined from the analysis of the data from the actual herd. By calculating input and output from the process and the states of the individual animals, the herd level production would be estimated or predicted. Because the model is stochastic, repeated simulations based on exactly the same data would produce different results. Replicated simulations would thus allow variance estimates to be estimated. Such estimates are crucial to evaluate risk in relation to decision making in management. In essence, the approach would allow herds to "relive their lives" with or without some relevant management change that may contribute to promote health in the herd.

A PRACTICE LEVEL EXAMPLE

A veterinary practice might wish to monitor health and production in client herds in order to rank their performance. Thus, poorly performing herds could be offered some intensive herd analysis and highest performing herds could serve as examples to inspire other farmers to promote animal health. Such an "among herds" approach was suggested by Schwabe (1991).

A considerable number of health and production indicators are relevant for monitoring herd performance. A simple ranking of each performance indicator may be insufficient to evaluate overall performance because correlations among variables may be strong. To overcome this problem, a second order factor analysis was applied to 22 herd level performance indicator parameters derived from the individual animal level analysis. The factor analysis identified five orthogonal latent variables describing production, replacement, and health (Enevoldsen et al., 1996). That is, five uncorrelated new and unobservable (latent) variables appeared sufficient to describe the common variation among herds. This approach has not yet been presented to veterinarians and farmers.

These latent variables would allow the veterinarian to identify distinctly different types of herds. These "case-herds" would then be studied in more detail. E.g., the veterinarian could collect more data from the herds to test specific hypotheses or use herd data for simulation experiments as described above. Because the case-herds are selected through a systematic approach with inter-correlations accounted for (by using the values of the latent variables), a pattern of responses would be described to represent the relation between determinants of herd performance (e.g. farmer attitudes or housing system) and responses of interest (e.g. options for increased profit or better milk quality). That is, a response surface would be constructed. This response surface could be used to select examples of typical client herds for discussion of health problems with a given herd owner. A subset of herds representing all combinations of extreme values of the five latent variables could be subjected to an economic whole herd analysis. This would allow the potential profit from disease control to be estimated at the practice level.

DISCUSSION

This paper proposes a bottom-up approach to epidemiological modelling, i.e. a systematic collection of carefully analysed "cases" (animal or herd level) where a given problem or a sequence of events has been thoroughly analysed by suitable statistical methods combined with qualitative aspects where appropriate. General trends and patterns characterising these cases would then be identified with similar methods. Such a bottom-up approach could also be called a meta-analysis. The methodology also has similarities with Bayesian statistical methods which allow a prior (qualitative) knowledge to be accounted for. The examples indicate that quantitative statistical methods are very useful to identify animals or herds of interest and estimate how different they are compared to some reference categories. Often the direct causes are better identified with a combination of quantitative and qualitative methods in an iterative fashion. In that process regular herd visits appear very important.

Such an approach appears to fit well with the concept of health promotion defined as "the combination of educational, organisational, economic, and environmental support conducive to health". If the goal of research is to provide a better foundation for health promotion, it is crucial to integrate research and herd health management activities in veterinary practice. A current activity to obtain such an integration is the planning of a course where the tools described above (and others) are introduced to specialised veterinarians. The course will allow participants and scientists to work interactively with the participants' client herds. Major specific goals of the course are to detect weak points in the approaches, identify options for improvements, establish contacts with more veterinarians and herds and develop practically applicable herd health management programs.

CONCLUSION

Close collaboration with practising veterinarians regarding herd health management issues has shown that a combination of quantitative and qualitative data analyses is necessary and very useful for decision support. In particular, the clinical observations made at herd visits and the feed-back from discussions with the farmer appear to contribute important qualitative data. This paper provides examples that suggest how quantitative and qualitative data can be combined into one analytic framework comprising animal, herd, and practice levels.

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NUTRITIONAL EPIDEMIOLOGY IN SMALL ANIMAL MEDICINE

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Nutritional epidemiology is the study of diet, nutrition, and feeding practices as potential causes or treatment of disease in populations (Willett, 1990). Recently, there has been increased interest in nutrition, diet and disease in small animal medicine both from an etiological perspective as well as for treatment of disease. Many diseases are multifactorial, potentially caused by a combination of diet, environment and genetics. This makes it critical to be able to assess the role of diet, nutrition and disease occurrence in dogs and cats. The objectives of this paper are to: 1) identify problem areas in small animal nutritional epidemiology, 2) briefly illustrate these problems using examples from the literature and 3) present a review of the methods of dietary data collection as extended from human nutrition into small animal populations.

Nutritional epidemiology is a fairly well developed field in human beings. Similarly, nutrition has long been considered an important factor in disease and production in food animals. There are many principles and concerns that nutritional epidemiology in humans and food animals have in common with dogs and cats. These include accurate assessment of intake and nutrient analysis of the actual feedstuffs. However, compared to small animals, food animal nutrition is more focused and organised because it is part of a relatively structured management program with practical economic constraints. In human beings, there is typically much less structure and more different types of foods than in animals. However, there are existing survey instruments with well documented reliability and validity that are available for use in a wide variety of human populations (Thompson & Byers, 1994).

Compared to many dietary assessments in human beings, all animal diets, unless directly observed, are collected from surrogate responders, the owner or caretaker. There are several additional problems inherent in small animal nutritional assessment. While commercial diets may add consistency to dog and cat feeding patterns, these diets may also change across relatively short time periods or assays of the content of specific nutrients may be unavailable. Dogs and cats typically have more structure to their eating habits than human beings (especially in places where commercial foods form the main part of the diet); however, they may also be fed homemade diets (either carefully made to be complete or consisting of left over foods) or table scraps. These foods may reflect owners eating habits, further complicating assessment of pets' diets by owners recall of their own diets. Owners perceptions of "appropriate feeding" may also influence feeding patterns, especially in the case of

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overfeeding or supplementation. Management situations, such as multiple animal households where animals eat from each others bowls or free-choice feeding, make individual animal intake assessment almost impossible.

PROBLEMS IN STUDYING DIET AND DISEASE

Nutritional epidemiologists usually approach diet as a potential etiologic agent or treatment for a disease (Slater & Scarlett, 1995). Diet can cause disease by three main mechanisms. The first is a dietary deficiency of specific nutrients or required components. The second is dietary excess of a specific nutrient or calories. The third category is management factors relating to diet, including frequency of feeding and type of foods (eg, dry or canned, high protein or reduced calorie). Diet as a treatment of disease has three main objectives. The first is to control the disease and improve the animal's quality of life. The second is to cure the disease, and the third, to improve health and well-being as a supportive treatment in conjunction with other treatment modalities.

Overall, there are three main obstacles to understanding the epidemiology of nutrition in small animals. The first is a dearth of epidemiological research in populations of animals with naturally occurring disease. The second is a relatively limited integration of epidemiology and laboratory or basic research. The third problem is a shortage of basic information about the physiology and pathophysiology of the animals themselves.

Shortage of studies

The dearth of epidemiological studies is reflected by few studies of any sort in some areas or by poorly designed studies (often by scientists with little or no epidemiological training). The existing studies often have limited sample sizes or may have an inappropriate or completely absent comparison group, even for observational study designs. There is also a shortage of information on such basic questions as incidence and prevalence of disease and its natural history (including etiology, usual age of onset and outcome). This lack of basic information makes it very difficult to design studies intelligently. Consider, for example, dietary management through protein restriction for chronic renal disease (CRD) in dogs. There have been very few epidemiological studies in clinical cases. A review article in 1993 (Kronfeld, 1993) found only four clinical trials using protein restricted prescription diets. In these studies, there may be very small numbers of animals. Two studies included fourteen and nine dogs, respectively, divided into different treatment groups (Barsanti & Finco, 1984; Hansen et al., 1992). The evaluated diets also may change more than one factor (protein and phosphorus and calcium and sodium) (Kronfeld, 1993) making it difficult to draw conclusions about protein restriction as a treatment for CRD.

Chronic renal disease in dogs can further illustrate other limitations in nutritional epidemiology. In the literature, there are two fundamental assumptions about CRD in dogs upon which clinical care and basic research have been based (Brown, 1992). The first is that the disease in dogs is inherently progressive and that diet could halt or slow this progression. Specifically, reduced protein in the diet decreases azotemia which improves the dog's quality of life. The second assumption is that experimental models of CRD using partial nephrectomy in the dog and in rats are good models for the spontaneously occurring canine disease. Since we know very little about the natural history of

CRD in dogs (Churchill et al., 1992) including the usual progression in clinical cases, it is very difficult to get a clear picture of the appropriate treatment protocol.

Limited integration and collaboration

With limited financial resources and the need to use as few experimental animals as possible, it is critical to improve integration of epidemiological and laboratory or basic research. Collaboration and communication with researchers in other regions and countries are vital. The arguments for protein restriction for CRD in dogs are based on the hyperfiltration theory which evolved from information on CRD in rats (Gonin-Jmaa & Senior, 1995). The basis of the theory is that decreased function of the kidney causes adaptations in the nephrons including glomerular hyperfiltration, hypertension and enlargement. These changes eventually lead to glomerular damage and progression of renal dysfunction, perpetuating the cycle. Brown (1992) has proposed a series of sensible experimental questions to address this hypothesis. If this theory is not true in dogs (and limited clinical trials suggest that low protein diets may not be helpful clinically) then we may be worsening the health of canine patients because of the treatment intervention. Additionally, the fallacy that older dogs' kidneys are "overloaded" by unnecessarily high protein levels in the diet has persisted (Brown, 1992; Kronfeld, 1993) and is promulgated by lower protein diets for older pets marketed by pet food companies. What little work is available in older animals suggests that moderate levels of protein (usually higher than are found in diets marketed for older animals) are most appropriate (Kronfeld, 1993).

Unacknowledged complexity of biological systems

The inherent complexity of biological systems and our limited ability to assess them also make it more difficult to evaluate diet and disease. In CRD in dogs, levels of disease severity (measured differently by function tests and serology), limitation in early diagnosis of renal disease, variable terminology and potential multiple underlying causes of decreased function all contribute to the confusion (Bovee, 1992). For lower urinary tract disease (LUTD) in cats the relationship between cause and treatment have been further obscured. Unlike CRD, potential predisposing factors for LUTD in cats were relatively well studied (for a small animal health problem) in the 1970's and 1980's using epidemiological methods (reviewed by Willeberg, 1984). However, the complex interplay of dietary magnesium, calcium, phosphorus and urinary pH was not fully recognized (despite a recommendation to address these in 1973 (Baker)). The lumping together of several, probably distinct disease entities under the syndrome of feline urologic syndrome or FUS, may have further obscured our understanding of these health problems (Osborne et al., 1994). Again, more information on the natural history of urethral obstruction, urolithiasis, bacterial cystitis and idiopathic cystitis (feline interstitial cystitis) would have clearly pointed out the distinctions between these health problems and the different diagnostic and therapeutic approaches needed. To focus on struvite crystals and urolithiasis, the cure of urine acidification and decreased magnesium in the diet, appears to have led to an increase in a different disease, calcium oxalate urolithiasis (Osborne et al., 1994). In addition, acidifying diets may be causing hypokalemia (no epidemiological studies have been published) which may be linked to CRD (which we know even less about than the disease in dogs) (Buffington et al., 1994). Here confirmation that the "cure" was not worse than the disease might have provided valuable insight. LUTD in cats is now in a new stage of understanding with a recognized need for evaluation of acidifying and low magnesium diets, calcium oxalate urolithiasis and kidney function. Additional studies on predisposing factors for idiopathic LUTD must also be conducted and must address dietary, stress-related and other environmental variables (Slater & Scarlett, 1995).

METHODS OF DIETARY DATA COLLECTION

Organisation of study

There are three major choices which, in addition to financial constraints, will partially determine the best data collection method. The following discussion, as it pertains to collection of dietary data from human beings, relies heavily on the Resource Manual compiled by Thompson and Byers (1994).

Purpose of the study: First, what is the purpose of the study? Is it to determine usual daily intake of specific foods or nutrients or to assess dietary behaviours or management factors? Is the objective to quickly screen individuals to identify those for whom interventions will be most useful? For example, a series of questions about body condition, breed, types or amounts of foods, etc., might be used to target educational information to owners of dogs with a tendency towards obesity. Is the purpose to measure absolute or relative intake (to compare absolute nutrient intake to a recommended intake or to rank animals in the study relative to one another)? How accurate do the data need to be (or how precise)?

Time period of interest: Does the study design need to collect recent information or usual dietary patterns for a long period of time? Is the information to be collected prospectively or retrospectively? Is there likely to be seasonal variations or day of the week variability that needs to be accounted for?

Population to be studied: How will owners be identified? Will the information be collected face-to-face, by telephone or by mail? What is the literacy level of owners? Are there regional or ethic differences in feeding patterns, availability of commercial diets or types of table foods?

Major data collection options

I have included information on questionnaire types as well as a description of most of the published dietary questionnaires in small animals. There are three main types of questionnaires (Thompson & Byers, 1994). The first is the daily diary or record. The second is the 24 hour recall and the third is the diet history. General recommendations for different study designs and time periods have been made in human nutritional epidemiology. For cross-sectional studies of recent diet, recalls have often been used successfully. For retrospective studies involving long time periods, dietary histories are the only approach. For prospective collection of data, any of the methods will work, depending on other constraints. When possible, recalls and diet histories should be used in conjunction with daily diaries. Data collected from the diary can then be used to adjust or calibrate the other methods to some extent.

Daily diary: The daily diary or record involves the owner recording all foods fed each day for the duration of the recording period. Typically, data will be collected for three and seven days (Willett, 1990). After seven days, respondents tend to keep less accurate records. My experience with seven day records kept by dog owners has been very positive. If less than one week is used, variations between weekdays and weekends, especially for people who work or have children, must be taken into account. The diaries can be completely open ended without any structure or can be divided into section for dog foods, treats, table foods, supplements, etc. Even with the more structured approach, coding can be somewhat time consuming. This technique is often considered the "gold standard" of dietary measurement in the absence of the ability to actually observe the dietary patterns. There is the potential to bias the sample toward highly motivated and literate owners with this technique. Also, the actual process of recording the diet may result in changes toward what owners perceive to be more appropriate feeding patterns (eg, less treats or table foods, smaller amounts of dog food).

Two studies have used seven day diet records in conjunction with diet histories (Sonnenschein et al, 1991; Slater et al., 1992). Both studies collected data for use in case-control studies in dogs and presented absolute intakes, relative intakes (eg, percent total calories) and made assessments of agreement between the diet history and record. In both studies, correlations between the two methods were variable, ranging from about 0.4 to 0.9, depending on the specific food or nutrient. In general, correlations for relative intake measures were higher than absolute measurement.

Twenty-four hour recalls: Twenty-four hour recalls are used to assess intake in the previous day or 24 hour period. Usually multiple recalls are needed to collect an accurate picture of intake if actual estimates of nutrients are needed. If only an average intake for a group is needed, a single recall may be adequate. Recalls are usually done in face-to-face or telephone interviews because the skill of the interviewer is critical to obtain complete information. A very structured interview with pre-planned probing questions is necessary for the best results. Probes should include asking about preparation of table foods and between meal snacks. The advantages of recalls are that they are relatively quick to complete and do not require a highly literate individual. There should be little interference with usual dietary patterns. The main limitations of recalls are that they rely on memory and they provide only a one-day window on typical dietary patterns. When compared to diet records of human diets, the recalls sometimes overestimate and sometimes underestimate intakes. I am not aware of any published recalls in the small animal literature.

Diet histories: I have included here with the more traditional dietary history, modifications of the traditional history questionnaire and the food frequency questionnaire (and its semi-quantitative version) because all assess **usual** past diet in relatively general terms. The original dietary history as developed by Burke (1947) for human diet assessment included details about the usual pattern of eating, a food list with amounts and frequencies and a three day diet record. Typically, both in human and veterinary medicine, a diet history currently refers to a questionnaire that includes information about usual past diet, including preparation of foods, amounts and frequencies. Modifications of the dietary history include questions about commercial diets (dry, canned/tinned and semi-moist), treats, table foods (including details on amounts and preparation) and supplements. These questionnaires are usually designed for telephone or face-to-face interviews, requiring interviewer recruitment, training and supervision. Like the recalls, owners must respond based on their memories of frequency and amounts of food. This can be a source of potential bias for dogs and cats fed a lot of treats or table foods or whose diets have been very varied.

Food frequency questionnaires in their pure form provide a list of foods and request an estimate of frequency of consumption. These questionnaires are not usually arranged by meal or day but rather by listing of foods in groups. Usually, there is little information on preparation or amount of dog foods or table foods. The semi-quantitative version includes usual portion sizes in the food list. Frequency questionnaires are commonly used for human dietary assessment because they can be self-administered and are relatively quick to complete. They are considered relatively good for use in studies for establishing a statistical association, but due to the lack of detail, are not good for determining the size of the association. Further, these questionnaires are very sensitive to the population used and must be validated in each distinct population. For dogs and cats that are fed primarily a commercial diet, a food frequency questionnaire would only provide a list of commercial foods fed. For populations where pet diets consist of mostly human foods, the food frequency questionnaire may be useful. Neither the food frequency questionnaire or the semi-quantitative version are very useful if actual intakes of nutrients are needed; I would expect these types of questionnaires would also be of limited value for relative intakes of dogs due to the large variation in body sizes and hence in portion sizes.

In small animal epidemiology, diet histories consist of three main types. The first is a modified diet history which includes detailed information on frequency, types of foods and amount which allows actual nutrient intakes to be calculated as well as information on specific food items. The level of detail presented in the published report varied, ranging from a brief mention of "detailed dietary intake information" (Donoghue et al., 1991) to explicit evaluation of the questionnaire's performance (Slater et al., 1992). Sonnenschein's work (1991) provided some detail in the publication; additional information was available in her thesis (Sonnenschein, 1988). The questionnaire used by Slater et al. (1992) was modified to improve repeatability (Slater et al., 1995).

The second type of history is similar to the food frequency questionnaire. Food lists are used and the frequency or proportion of each food in the diet is requested. Most of the work in LUTD in cats used this type of questionnaire for collection of dietary data (Willeberg, 1975; Walker et al., 1977; Reif et al., 1977; Jones et al., 1994). These studies address the use of canned and dry commercial diets as well as the inclusion of table foods or home-made diets. One case-control study of hyperthyroidism included detailed information on all foods fed but not exact portion amounts (Scarlett et al, 1988). A study of obesity in dogs in the United Kingdom also included information on foods fed and relative proportions in the diet (Edney & Smith, 1986). None of these studies provided information on repeatability or validity. However, the questionnaire used by Scarlett et al. (1988) is currently being evaluated for repeatability and validity compared to a daily diary (Scarlett, 1995).

The third type of history questionnaire is only loosely allied to the diet history. Often, diet is one component of an investigation and is evaluated only by a list of foods fed. Owners are asked to state whether or not they feed the listed foods. Two studies of obesity, one in cats in the United States (Scarlett et al., 1994) and one on dogs in the United Kingdom (Mason, 1970), included questions about whether or not commercial diets, table foods and home-made diets were fed. One cross-sectional study about dog behavior (a convenience sample of 1422 dog owners) included a question about usual feeding patterns (frequency of feeding each day and use of table foods)(Campbell, 1986). A case series on muscle weakness syndrome in 40 cats (hypokalemia), included questions about the type and brand of cat foods fed (Dow et al., 1988). A more recent study on hypokalemia in cats also included a "diet history" (Dow et al., 1989). Only information on specific types of foods and certain brands were used in the analysis. Duration of feeding of each diet, portion sizes and frequency of feeding were not ascertained. A case-control study on risk factors for bladder cancer in dogs included a set of questions on diet and body condition (Glickman et al., 1989). Owners were asked whether canned, semi-moist or dry commercial dog foods were fed.

Based on this review, there is a paucity of standard survey instruments for use in collecting dietary data on dogs and cats. The majority of studies have not gone beyond simple questions of which type or brand of commercial food was fed. For more sophisticated investigations of diet, alone or in combination with other potential risk factors, reliable and valid questionnaires must be developed and used. The assumption has been made that owners can reliably report the brand and type of food fed in the recent past as was requested in the brief diet histories above. In most cases, this assumption has not be examined. A short questionnaire could be developed and evaluated for this use. In many situations where diet is thought to be an important factor, a more detailed questionnaire that will allow frequency of feeding, duration of diet or actual nutrient intake to be calculated may be most appropriate.

Several additional assumptions underlie our current approaches to nutritional epidemiology in small animals. The first is that the relatively short life-span of dogs and cats allows most dietary exposures to occur relatively recently (compared to the situation in humans where dietary exposures 20 or more years ago may be important). This would allow more accurate assessment of past diet when relying on owner memory. The second is that commercial diets are in widespread use and the contents of these diets are available. This is true in most of the United States but may not be the situation in other countries. Further, commercial diets have proliferated in the United States at a great rate, making it difficult to maintain a complete database. The third assumption is that feeding patterns for dogs and cats are relatively consistent. This is the least defensible assumption at present since there is relatively little data on typical feeding patterns of dogs and cats and no longitudinal data at all. It seems likely that puppies and kittens may be fed different foods in different patterns than adults. It is also possible that older animals' diets become more variable due to illness, increased fussiness in eating habits or the tendency of owners to give more treats. I also believe that there may be differences between very small dogs and medium to large sized dogs based on owner and dog lifestyles and owners' reasons for acquiring the different breeds. Therefore, one must be cautious in assuming that dietary patterns are consistent across time for all breeds and species.

The obstacles to nutritional epidemiology I have presented above are not unique to the nutritional side of small animal epidemiology. These problems must continue to be addressed by epidemiologists and other research scientists in order to advance the science of small animal veterinary practice. The guidelines outlined in the methods section have only begun to be implemented in the small animal field. More details on the methods used should be published and made available to other researchers. Questionnaires should have some assessment of reliability and validity especially if used as the main instrument for data collection. Finally, assumptions about dietary patterns across time in dogs and cats should be tested.

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INTEGRATED DAIRY HERD HEALTH PROGRAMS - THE ISRAELI EXPERIENCE

ODED MARKUSFELD-NIR*

Veterinary medicine has traditionally centered on individual animals. Since emerging new problems have been mostly multifactorial, a new "multivariate approach" has been required. The outcome has been the initiation of integrated programs for herd health. These programs are characterized by the adoption of a population approach to clinical entities. Preventive measures and routine examinations are the hard core of such programs, but deeper involvement in nutrition, production and economics is needed (Radostits and Blood, 1985). Additionally, when considering a herd medicine approach, there should be no loss of ground in individual cow medicine. However, the application of similar methods to both small and large herds can cause difficulties.

THE ISRAELI DAIRY SYSTEM

The Israeli dairy system is centralized. The National herd consists of 120,000 milking cows (all Israeli Holsteins). In 1994, total production of milk was 1,049,252,000 litres with 3.16% fat, and 2.99% protein (MMB Report, 1994).

The Israeli Cattle Breeders' Association (ICBA) is a cooperative society. It maintains the Israeli Holstein Herd Book, performs milk-recording and operates the central laboratory for milk testing. The ICBA runs a centralized computer, where all information regarding dairy cattle is held. The ICBA has two affiliated organs which provide AI services to all, and veterinary clinical services to the vast majority of, dairy herds in the country.

More than 90% of the veterinary clinical services are supplied by the Hachaklait, the Mutual Society for Clinical Veterinary Services and Livestock Insurance in Israel. Hachaklait is characterized by being nationwide, mutual and by the comprehensive service given under contract. Hachaklait deals with the preventive and clinical aspects of herd and individual animal medicine. This is done by treatment of sick animals, running routine examinations, following up herd reports, offering consulting services and supportive laboratory services. Consulting services include nutritional, infertility, toxicology, parasitology, and advice on calf, sheep and equine diseases. Consultants are either full time employees or practicing veterinarians who are rewarded for their expert services. Other special services given by the company are roentgen and bull fertility evaluation.

*"Hachaklait" the Mutual Society for Insurance and Veterinary Services in Israel, 57 Balfour Street, Nahariya 22426, Israel.

The Israeli dairy herd operates under strict milk quotas. More than 80% of the national herd are registered in the Herd Book (204 Kibbutz, and 598 Moshav, family owned herds respectively). Mean yield was 9,748 kg per cow in 1994. Mean pregnancy rates from first service were 63.6%, 42.6%, and 34.7% for heifers, primiparous, and multiparous cows respectively.

We began to explore the new fields of herd health in the early eighties. Due to the unique structure of the Israeli dairy industry and the centralization of the veterinary clinical services, we have succeeded in turning many people's dreams into a reality. Under free market conditions, and confronting severe competition, herd health programs were introduced to the vast majority of the farms in the country. The essential steps to obtain our goals were: a) Setting targets and defining problems; b) Introducing new practice routines involving more routine examinations in both herd and individual cow levels; c) Developing methods of routine monitoring and causal analysis at farm level; d) Convincing both farmers and veterinarians of the need for change; e) Teaching the new methods to veterinarians, and finally f) Evaluating the results. The various stages are briefly described in the present paper.

HERD HEALTH PROGRAMS

Herd health programs are balanced between individual cow and herd medicine. The main components of the integrated herd health program practiced by us are outlined in Table 1. The general outline and aspects of individual cow medicine have been described previously (Markusfeld-Nir, 1993). Some of those dealing with the herd approach will be described.

Table 1. Integrated herd health program.

The cow	The herd
1. Early professional treatment. a. Early diagnosis of clinical and sub-clinical diseases through routine tests. b. A regular presence on the farm. c. Treatment by veterinarian.	5. Processing data. a. Establishing targets. b. Issuing monitoring reports.
2. Prevention of disease. a. Follow up of feeding plans. b. Advancement of vaccination and prevention plans.	6. Intervention. a. Epidemiological evaluation. b. Conclusions. c. Cost/benefit evaluation. d. Recommendations.
3. Use of "real time" laboratories.	7. Evaluation of results.
4. Recording of data.	

Herd health monitoring is performed on populations, not on individuals. Individual cow data are still essential if interactions between factors are to be clarified. Routine tests allow for an early diagnosis of both clinical and subclinical diseases. When carried out in a uniform way, and on all animals, they also supply the data needed for future analysis. To cross the line from individual to herd medicine, data are recorded and processed in order that both statistical and epidemiological evaluations can be carried out. The relationships are further explored by causal studies. Some aspects of the system as evolved in Israel will be discussed.

ANALYSIS OF CALVING, REPRODUCTION, AND PRODUCTION DATA.

A routine monitoring and analysis of health and fertility indices are carried out every four months on all Kibbutz farms, members of the Hachaklait. Relevant data are processed at the Hachaklait and reports are routinely issued and evaluated. The routine is described in Fig. 1.

ROUTINE POST -PARTURIENT EXAMINATION ↓ | CALVING & REPRODUCTION DATA ↓ → FARM COMPUTER ↓

MONTHLY MILK RECORDINGS (MILK, FAT, PROTEIN, SCC) ↓ ↓ → HERD BOOK COMPUTER ↓

DATA PROCESSING (HACHAKLAIT)
↓ ↓

<u>MONITORING REPORTS</u>

CALVING TRAITS

FERTILITY

LACTATION CURVES

ABORTIONS

<u>CAUSAL ANALYSIS REPORTS</u>

<u>FERTILITY</u>	<u>PRODUCTION</u>
CONTRIBUTION TO "NOT-PREGNANT FROM FIRST SERVICE	FACTORS FOR LOSS OF PEAK YIELD
CONTRIBUTION TO "OPEN DAYS"	FACTORS FOR LOSS OF 305-d EXTENDED MILK YIELD
CONTRIBUTION TO ANESTRUS	

Fig. 1 Analysis of calving\fertility\production data (A flow chart).

MONITORING REPORTS

Monitoring reports are designed to provide ongoing monitoring of herd performance which is compared to preset targets of performance (Radostits and Blood, 1985). The reports alert against any fall from preset targets, and, as such, are short, concise, engulf all aspects of herd health and are issued regularly (Bartlett et al, 1986).

We issue routinely reports which deal with calving traits and diseases, reproduction, lactation curves and abortions. The latter reports present a multifactorial analysis which control the effects of lactation number, trimester and date of abortion. Complete monitoring reports covering most major health and economic aspects are issued only to selected farms having reliable data. An example of a monitoring report (the section dealing with periparturient traits and diseases) is presented in Table 2.

Table 2. Monthly monitoring report (Calving Traits).

	Values in brackets are TARGETS			
	Heifers		Cows	
a. n Calvings	131.0		197.0	
b. % twins	*2.3	(1.0)	*7.1	(5.0)
c. % stillbirth	6.0	(8.0)	*6.2	(5.2)
d. % milk fever	0.0	(0.0)	*5.1	(1.0)
e. % prolapsed uterus	0.0	(0.7)	*1.0	(0.7)
f. % displaced abomasum	0.0	(1.0)	0.0	(1.0)
g. % retained placenta	*14.6	(11.4)	11.3	(12.2)
h. % primary metritis	*33.8	(21.5)	12.4	(15.0)
I. % ketosis	0.0	(1.0)	2.6	(5.0)
j. % calved with mastitis	*2.0	(1.0)	1.0	(5.0)
k. % daydry >70 d			*43.7	(15.0)
l. % daydry <55 d			2.0	(15.0)
m. % induced calving	*14.5	(7.5)	*6.1	(2.0)
n. % with body score≥4.25	4.8	(15.0)	0.5	(15.0)
o. % with body score≤3.00	11.1	(15.0)	*31.8	(15.0)
p. BCS changes in dry period				
1. n examined			172.0	
2. % lost>0.5 units			*37.2	(15.0)
3. % gained>0.5 units			1.2	(15.0)

* denotes values short of targets.

EPIDEMIOLOGICAL DESIGNS

Aspects of monitoring and statistical reports have been extensively dealt with in the developing field of herd health. The statement that "Studies of clinical applications of quantitative epidemiological techniques are still rare" (Martin et al, 1987), still holds today. Epidemiological evaluations of factors responsible for decreases from targets should become routine. We routinely evaluate the contribution of various factors to lower fertility and milk yield at farm levels.

Factors responsible for lower milk yield are evaluated by three different models. The results are presented in subsections according to lactation number. The models evaluate factors responsible for lower milk peak yield, lower economy corrected peak milk yield (ECM), and for lower extended 305-d yield respectively. Linear regression models, in which the various estimates represent the losses attributed to the respective factors, are used. An example (dealing with factors responsible for loss of ECM peak yield) is presented in Table 5.

Factors responsible for lower fertility are evaluated by three different models. The results are presented in subsections according to lactation number as follows: a) Contribution to "non pregnancy from first service"; b) Contribution to anestrus; and c) Contribution to "open days". In the first two models (based on logistic regression methods) the respective contributions of the various factors to the indices are quantified. The third model is based on linear regression. The various estimates are the additional open days attributed to the various factors evaluated. The upper value for "open days" is 150-d, so most cows are included. An example for such a design which evaluates the contribution of various factors to the index "Not pregnant from first service" is presented in Table 3.

Table 3. Contribution to "non pregnancy from first service" (65 third and more calvers).

Factor	Incidence/quartile	Contribution (%)
Parturition diseases (%)	29.2	-4.1
Unobserved heat (%)	26.2	4.6
High yield before service (kg 3.5% FCM)	44.6	7.9
Short rest period (days)	64.0	-6.8
Low body condition score at calving (u)	3.25	17.6**
Long dry period (days)	68.0	2.4
Summer calvings (%)	15.4	6.5+
Common factors.		40.8
		69.0[a]
		64.6[b]

[a]Rate of non-pregnancy (model). [b] Rate of non-pregnancy (actual).
+p<0.1 *p<0.05 **p<0.01

The factors evaluated in the model are: a) Postparturient diseases (twins, retained placenta, primary metritis and ketosis); b) Anestrus. An unobserved heat before service; c) A high FCM before service. We assume that high yielders will be in a relative negative energy balance compared to their low yielder counterparts. A cow "with factor" is one that belongs to the highest quarter of FCM 3.5% in the first three month of lactation; d) A short rest period. A cow "with factor" is one that belongs in her lactation group to the lowest quarter of rest days. In our sample farm, 25% of cows were first served less then 64 d from calving; e) A low body condition score at calving. A cow "with factor" is one that belongs in its lactation group to the lowest quarter of BCS; f) A long dry period. A cow "with factor" is one that belongs in its lactation group to the longest quarter of dry period length; g) Summer calvings. A cow that calved from April through August; and h) Common factors. The residuals (not explained by the variables of the model).

In Table 3, 64.6% of the 65 third or more calvers were not pregnant from first service (35.4% pregnancy rate). Cows in the lowest quarter of body condition at calving and summer calvers contributed 17.6% and 6.5% respectively to "non pregnancy". Steps to improve fertility can now be initiated. When intervention is called for, narrowing down the field of investigation often proves essential if results are to be obtained (Fetrow et al, 1987). This selection process enables the clinician to concentrate efforts and resources, in clinical and laboratory investigations, in the most promising directions.

Conclusions are drawn from the epidemiological study and the proposed recommendations are weighed with cost/benefit considerations. Possible losses are quantified and used with expected return value in decision analysis.

An example for such an evaluation is presented in Table 4. Possible economic returns from introduction of a pedometer system are estimated as follows: a) Additional open days due to double cycles and preservice anestrus are respectively calculated from the monitoring report and the causal analysis; b) The results are compared to the average performance of a pedometer system; c) The expected saving in cost is evaluated and weighed against the price of the system. Our sample farm has 261 cows, 51.4% preservice anestrus, 486 estrous cycles and 25.6% double cycles (37-60 days). Estimated additional "open days" for preservice anestrus was 14.9 days and an "open day" was estimated at $US 3.00.

Table 4. Estimated possible return from a pedometer system.

	Additional open days		
Item	Report	Pedometer[c]	Difference (US $)
Double cycles	2986[a]	1749	3711
Preservice anestrus	2998[b]	1167	5493
Total	5984	2916	9204

[a]Additional open days for double cycles=.256 (proportion of double cycle)*486 (n cycles)*24 (mid point of a double cycle); [b]Additional open days for preservice anestrus=14.9 (estimated additional open days for a cow with anestrus)*.514*261 (n cows with anestrus)*1.5 (correction factor). [c]Respective mean values for preservice anestrus and double cycles in pedometer farms are 20.0% and 15.0% respectively.

It is advisable that recommendations for changes are agreed by the farmer and the veterinarian in order that the chances of their being carried out are higher.

REEVALUATION

Any changes introduced should be reevaluated after a time. Changes made in the ration fed to dry cows following poor body condition at calving are evaluated in Table 5. Losses (measured in kg ECM peak yield) associated with BCS at calving in the period 07/93-06/94 are now greatly reduced (period 11/93-10/94).

Table 5. Effects of body condition at calving on ECM (economy corrected milk) peak yield (kg). Comparison between two periods.

FACTOR	1st LACTATION Incidence or Quartile	1st LACTATION Milk lost#	2nd LACTATION Incidence or Quartile	2nd LACTATION Milk lost#	≥3rd LACTATIONS Incidence or Quartile	≥3rd LACTATIONS Milk lost#
Period 07/93-06/94.						
Calving diseases	37.2	-0.3	31.7	-1.2	40.2	-0.4
Summer calvings	26.7	-0.6	48.8	-2.0	18.5	-3.4**
Low bcs at calving	3.25	-1.4	2.75	-4.2*	3.00	-2.1*
Short dry period			59.0	-0.5	59.0	1.8
Period 11/93-10/94.						
Calving diseases	36.8	-0.6	35.1	-1.7	33.8	-1.3
Summer calvings	23.7	-0.6	45.6	-1.4	16.2	-0.8
Low bcs at calving	3.25	-0.8	3.00	-2.5+	3.25	-0.1
Short dry period			56.0	-2.5+	60.0	1.2

+p<0.1 *p<0.05 **p<0.01

ASSIMILATION OF THE NEW KNOWLEDGE

The transformation has not been easy for veterinarians. The difficulties encountered are not surprising considering the basic motivation that leads most veterinarians to choose their profession: the love for animals and the drive to heal them. Veterinary schools find the changes needed difficult. Students still devote their time to the study of etiology, pathology, diagnosis and therapy of diseases of the individual animal. Prevention of diseases is treated only from the narrow aspect and briefly mentioned in standard textbooks. This training regime leads the graduate to treat clinical problems with a "monovalent" approach, while most problems are multifactorial. As such they call for a different "polyvalent" approach and training.

New knowledge had been passed to veterinarians through an 18 month course in Herd Health held in 5 hour weekly meetings. The meetings brought many veterinarians back to regular schooling for the first time since graduation. Out of 27 participating vets, 19 took and 15 passed the final examination. The course involved lectures, workshops, homework, and periodic examinations. A textbook was written for the participants. The program (Table 6) was set to include both theoretical background and simple tools to apply in practice.

Table 6. Course in Herd Health for practicing veterinarians (main topics).

Subject	Hours
1. Basic subjects	
a. Introduction to biostatistics	25.0
b. Computers	55.0
c. Introduction to epidemiology	7.5
d. Practical aspects of nutrition	32.5
e. Production economics	17.5
2. Herd health (introduction, monitoring & lactation curves)	37.5
3. Specific subjects (herd health aspects)	
a. Replacement heifers	22.5
b. Periparturient diseases	12.5
c. Reproduction	20.0
d. Abortions	17.5
e. Udder health	17.5
f. Infectious (notifiable) diseases	10.0
g. Parasitic diseases	10.0
Total	285.0

THE CONTRIBUTION TO THE NATIONAL HERD

The relative contribution of the course and routine reports issued to farms for the progress of the various herds can be evaluated (Table 7). Reports were issued in 1993 to 111 out of 187 Kibbutz herds which had a full set of data. Rates of reports issued to herds treated by participating and not participating veterinarians in the course differed (77.1% and 48.7% respectively).

The starting line (rates of traits in 1992) in the various groups was similar. Both herds treated by participating vets (PAR) and herds using Health Reports (REP) significantly improved compared to herds without those factors (NPAR/NREP). The greatest improvement was in herds that were both treated by participating veterinarians and using Herd Health Reports (PAR/REP). Milk yield per cow increased by 470 kg of milk in two years compared to an increase of 245 kg of milk in NPAR/NREP herds. A similar tendency (not statistically significant) was in the reduction of the SCC. PAR/REP herds also obtained better results in the field of reproduction. Overall pregnancy rates in heifers increased in PAR/REP herds by 3.1%, while they decreased in NPAR/NREP herds by 0.9%. Rates of "Not pregnant within 150 DIM" of first lactation cows decreased by 1.7% and increased by 1.9% in PAR/REP and NPAR/NREP herds respectively. The differences in multiparous cows had the same tendency (respective increase of 0.5% and 2.4%). The greater reduction in stillbirth in PAR/REP herds was significant in multiparous cows only.

Table 7. The contribution of herd health reports and participation of veterinarians in herd health course to production and fertility traits.

	Course		Reports		Course & Reports	
Factor	Yes	No	Yes	No	Yes	No
Total farm	70	117	116	76	54	60
<u>305-d Milk yield, (kg)</u>						
Mean 1992	9757	9898	9865	9816	9809	9879
Change in 1994	+469	+318*	+431	+291*	+470	+245*
Estimated contribution	73		133			
<u>Pregnancy rate, heifers (%)</u>						
Mean 1992	57.8	57.7	58.2	57.1	57.8	56.9
Change in 1994	+2.8	+1.0	+3.0	-.3**	+3.1	-.9**
Estimated contribution	+.9		+3.1**			
<u>Open >150 DIM, primiparous cows (%)</u>						
Mean 1992	30.7	30.1	30.0	30.8	31.1	31.2
Change in 1994	-1.3	+1.3*	-.5	+1.5	-1.7	+1.9*
Estimated contribution	-1.8		-1.9			
<u>Open >150 DIM, multiparous cows (%)</u>						
Mean 1992	30.1	29.6	29.6	30.0	30.5	30.3
Change in 1994	+1.0	+1.9	+1.0	+2.5*	+.5	+2.4
Estimated contribution	-.3		-1.5			

*$p<0.05$ **$p<0.01$

Most herds served by graduates of the course were using Herd Health Reports. To separate those two factors and to control the various initial effects of both veterinarians and farms, the data were further analyzed using a linear regression model. Rates of the various indices in 1994 were the dependent variables. Participation in the course, using herd health reports in 1993 and the 1992 data were the independent variables. The results (Table 7) show that both participation in the course and using herd health reports contributed to the improvement in most of the indices evaluated. The contribution of the course was both direct and indirect via a better utilization of the Health Reports.

CONCLUSIONS

Health reports are issued today to most Kibbutz farms every 4 months. While the spread to the Moshav herds is slow, rates of Kibbutz herds using the reports in the years 1993, 1994, and 1995 were 59.3%, 64.7, and 86.7% respectively. The present paper has described a private experience of changing the traditional individual cow medicine into a new herd or population medicine. This was done on a national scale and under ordinary commercial conditions. It is the author's belief that this private experience could become more common if the following points are kept in mind: a) The nucleus of any program should be the clinical services. Any other consolatory services offered are of a supportive nature; b) Health programs should be rightly balanced between individual cow and herd medicine; c) Some form of "Contract Practice" should exist. "One Man Practice" might be unable to deal with the new practices required; and finally d) Palpation is not "herd Medicine".

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EPIDEMIOLOGICAL STUDIES OF AUJESZKY'S DISEASE: ERADICATION FROM A MULTIPLE HERD ENTERPRISE

N T KAVANAGH[1]

SUMMARY

In a survey of 85 herds representing 28000 sows, 10.6% of samples gave a positive result to the G1 antibody ELISA test and 29% of herds contained seropositive animals. Seropositive animals were identified in 6 herds which were not vaccinating and therefore at risk of a major aujeszky's disease (AD) outbreak. AD spread occurred primarily in association with the purchase of breeding stock of unknown health status. The disease was eradicated from 7 herds by twice yearly vaccination but failed in 13 herds, suggesting that twice yearly vaccination controlled the clinical signs of AD but failed to eradicate the virus from the farms. AD was eradicated from a 12000 place finishing unit over a period of 4 months by vaccinating weaners derived from herds with circulating virus twice and all others once only; on arrival on the farm. The cost of AD was calculated at 1p per kg bodyweight gain or IR £0.46 per pig, by comparing similar 9 month periods of production, before and after eradication. The total cost of AD to the unit was estimated at £25,000 per annum.

INTRODUCTION

AD, as a clinical entity, in Ireland, almost ceased in association with the introduction of AD vaccination approximately 13 years ago. The development of a new ELISA G1 antibody test made it possible to distinguish AD vaccinated pigs from infected pigs thus allowing selective culling of infected pigs from a vaccinated herd for eradication purposes (Van Oirschot et al., 1987). This system was subsequently to form the basis of large scale AD eradication programmes (Stegeman et al., 1992). The objective of the first part of this study was to examine the ability of inactivated AD vaccine, administered to breeding stock twice yearly, to eliminate AD virus from pig herds and to review factors which may have contributed to the survival and dissemination of the virus within and between farms. The epidemiological data collected from the practice aujeszky's survey were used to design an AD eradication programme for a 12000 multisource finishing unit. The objective was to eliminate AD virus from the farm and the supplying breeding units, and to compare unit production efficiency when AD was endemic with that achieved after AD was eradicated, with a view to estimating the cost of endemic AD to a multisource finishing unit. Muirhead (1983) examined the cost of an AD outbreak in four herds and concluded that the cost of the disease varied from Stg £8200 to Stg £18400 per 100 sow herd size depending on its severity in individual herds. Kavanagh (1984) conducted an investigation into the cost of an AD outbreak in a 370 sow herd selling finishers and estimated the cost of an outbreak of the disease at IR £34,000 or IR £9,000 per 100 sow herd size.

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THE PRACTICE SURVEY

The survey involved random serological testing of 25 - 30 adult breeding stock per herd by the Idexx[2] G1 antibody test. Herds which were vaccinating against AD used inactivated vaccine; free of the G1 antibody. A database was set up to co-ordinate herd statistics that were considered relevant to the eradication or dissemination of AD virus (see below).

PRACTICE SURVEY RESULTS

Ten point six percent of samples gave a positive result on the Idexx G1 antibody test and 29% of herds were identified as seropositive. Sixty per cent of herds regularly vaccinated against AD on a twice yearly basis. Fifty three per cent of herds used home reared gilts as replacements and 37% purchased health monitored gilts from herds which were known to be free of AD. It was encouraging to note that only 8 herds (9.4%) purchased gilts from sources which were not health monitored (Table 1). This is in marked contrast to the situation that prevailed in the Diesen trial where, in the initial stage, the majority of replacement breeding stock were of unknown health status and probably AD positive (Stegeman et al., 1992). Of the 25 herds which proved seropositive to AD only 19 were vaccinating so six were at risk of a major AD outbreak (Table 2).

Table 1. Aujeszky's survey; practice herd statistics

	No. Herds	Positive	Vaccinat	MD %[a]	HRG %[b]	HMG %[c]	Other %
Total	85	29	59	27	53	37	9.4
BW[d]	47	27	51	25	47	43	10.6
BF[e]	38	31	68	29	61	32	7.9

a Minimal disease [SPF] b Home reared gilts c Health monitored gilts
d Breeder weaner e Breeder finisher

AD ERADICATION WITH VACCINATION

Seven herds, varying in size from 70 to 900 sows, which had a positive clinical and serological history to AD proved serologically negative in the survey, suggesting that AD had been eradicated in association with the vaccination and management procedures which had been adopted over the previous 10 years.

[2]Idexx Corp, 100 Fore St., Portland Maine, 0401, U.S.A.

Eradication of AD was not achieved in a total of 4 out of 7 breeding herds which were vaccinating and selling weaners at approximately 32kg bodyweight, indicating that successful eradication of AD by vaccination alone was not achieved even when no finishers were present.

AD DISSEMINATION TO AD FREE FARMS

One AD positive farm was associated with the spread of the disease to 5 farms that were previously free of the disease through the sale of seropositive replacement gilts. The farmers in question, who were unaware that their stock were seropositive, were not vaccinating for AD and as a result at risk of a major outbreak of the disease (Table 2). A sixth farm, which purchased gilts from an MD herd, seroconverted to aujeszky's disease without developing clinical signs of the disease. The probable source of the AD virus in this case was from a multisource finishing unit belonging to the same organisation. The breeding stock on this farm were vaccinated at 6 monthly intervals, demonstrating that the virus can circulate in the presence of the above vaccination regime.

Table 2. Herds at risk

	Pos. Herds	Pos. Herd Vaccinating	Pos. Herds not Vaccinating
Total	25	19	6
BW[a]	13	7	6
BF[b]	12	12	0

a Breeder Weaner

HERDS WITH A SEROPOSITIVE INCIDENCE >/= 15%

Nineteen herds were identified by this system, 13 of which were vaccinating regularly, suggesting that twice yearly vaccination of breeding stock was capable of controlling the clinical signs of AD but failed to eradicate the virus from the farm. Four of the problem herds purchased health monitored gilts or MD gilts. Ten herds used home-reared gilts which increased the risk of virus circulating in the gilts before they reached maturity as replacement stock. Five herds purchased replacement breeding stock of unknown health status (Table 3).

Table 3. Herds with seropositive incidence >/= 15%

	No. Herds	No.Sows	Mean Herd Size	a Vac	HRG	HMG	Other
Total	19	6,945	365	13	10	4	5
BW	10	3,845	385	4	5	2	2
BF	9	3,100	344	9	5	2	3

a AD vaccinated

CONCLUSIONS OF PRACTICE SURVEY

1 Twice yearly vaccination of breeding stock with inactivated AD vaccines controlled the clinical signs of aujeszky's disease but failed to eradicate the virus from the farm. This also applied in breeder weaner units, where no finishers were present, since eradication of AD was not achieved in 4 out of 7 breeding herds which were vaccinating breeding stock and selling weaners at approximately 32kg bodyweight.

2 There is a risk of sero conversion occurring in home reared replacement breeding stock, so they should be reared in isolation from the grower stage and vaccinated twice as growers and a third time before they reach 6 months of age.

3 Where replacement breeding stock are purchased they should only be purchased from sources that are health monitored and known to be free of AD. Indeed, failure to follow this procedure was the major cause of AD spread in the practice herds since 1984.

3.1 Purchased sero negative replacement breeding stock should be quarantined and fully immunised against AD before being introduced to the breeding herd, thus reducing the risk that they should sero convert to the virus.

4 Identification of herds in which the virus is circulating should be accompanied by on-farm investigations of management, housing, the systems of pig movement, and to identify areas in which the virus is circulating. The objective is to maximise the probability of eliminating circulating AD virus from the farm in the shortest practical time in conjunction with intensive vaccination and culling of seropositive animals, otherwise virus excretion may continue in the presence of vaccination.

ERADICATION OF AD FROM A 12,000 PLACE MULTISOURCE PIG FINISHING UNIT

Weaners were sourced from 23 breeding herds. Blood-testing of pigs in the finishing unit and at slaughter by the G1 antibody ELISA test for AD gave a positive result on almost all pigs tested, so it was concluded that AD was continually circulating in the finishing unit (Table 6). A decision to attempt AD eradication from the farm was prompted by the presence of persistent respiratory disease problems in pigs on it; the objective was to eliminate a known disease and then to establish if other complicating diseases would become less problematic.

The results of the 1992 practice AD survey were used to identify AD positive suppliers; a random serological survey of weaners derived from all suppliers (June 1994) identified herds with circulating virus (Table 4). "Problem" suppliers (herds in which the virus was circulating) were identified by random sampling of pigs from all suppliers on arrival in the finishing unit.

Table 4. The incidence of AD seropositives in supplying farms in 1992 (sows) and in 1994 (weaners).

	Sows (1992)	Weaners (1994)
No. Farms	23	23
No. Positive	8	2

All suppliers were advised to purchase replacement breeding stock from AD free sources and to isolate and vaccinate them on arrival so that they could develop immunity before being introduced to the herd.

"Problem" suppliers were advised to vaccinate weaners at 8 - 10 weeks of age; a booster injection was administered on arrival in the finishing unit. Pigs were vaccinated with a live AD vaccine, Intervet Aujeszky's Live Begonia. All other pigs were vaccinated on arrival in the finishing unit. Home reared gilts were vaccinated at 8 - 10 weeks of age, 14 weeks and again at 6 months. Sows, boars and replacement gilts were vaccinated 3 times per annum (blanket vaccination). In each case the dosage rate was 2ml.

MONITORING AD ERADICATION PROGRESS.

When the programme was set up on 1 July 1994, the aujeszky's disease status of pigs derived from AD "problem" supplying herds was monitored over the following 6 months by blood sampling random pigs on arrival in the fattening unit in order to check for the presence of circulating virus (Table 5). By October 1994, 3 months after the introduction of weaner vaccination to "problem" suppliers farms, virus circulation had ceased. Also, blood-samples from random weaners derived from all supplying farms were tested in October 1994 and again in December 1994, with negative results.

Table 5. The incidence of AD SEROPOSITIVES IN PIGS DERIVED FROM FARMS WITH CIRCULATING AD VIRUS.

Date	No Tested	No Positive
01/06/94	6	4
01/06/94	6	4
06/10/94	6	0
31/10/94	6	0
21/12/94	6	0
22/12/94	6	0
20/01/95	6	0
20/01/95	6	0
20/01/95	6	0

THE RESPONSE TO VACCINATION

The incidence of AD seropositives in pigs slaughtered fell from 96% before the commencement of vaccination on 1 July 1994 (Table 6) to 15% in October 1994, 3 months later (Table 7). By November 1994, 4 months after the introduction of vaccination in the finishing unit, all serum samples tested were negative for AD and have remained so since then. The changes in seropositive incidence were statistically analysed by the chi square test ($P < 0.0001$).

Table 6. The incidence of AD seropositives before vaccination in a 12,000 pig finishing unit.

Date	No. Tested	No. Positive	% Positive
21/10/93	6	5	83.3
26/02/94	10	9	90
13/07/94	16	16	100
11/08/94	18	18	100
Total	50	48	96

Table 7: The incidence of AD SEROPOSITIVES AFTER VACCINATION IN A 12,000 PIG FINISHING UNIT.

Date	No. Tested	No. Positive	% Positive
28/09/94	10	2	20
04/10/94	10	1	10
13/10/94	10	1	10
16/11/94	17	0	0
19/11/94	26	0	0
02/12/94	10	0	0
21/12/95	10	0	0
10/01/95	10	0	0
TOTAL	103	4	3.9

Monitoring of vaccine usage on weaners in a problem suppliers farm

The efficiency of weaner vaccination was monitored by subjecting bloodsamples to the total ELISA and G1 antibody test. A positive result to the total ELISA test and a negative result to the G1 antibody test confirmed that the pigs had been vaccinated against aujeszky's disease.

AD Dissemination

One MD herd seroconverted to AD between July and October 1994. It is interesting that this herd has remained free of Mycoplasma hyopneumonia. The source of the disease was most probably aerial spread from an AD positive breeding herd which was located approximately one mile distant from the herd in question. The changed AD serological status of this herd was identified on routine serology of random pigs in the finishing unit. Evidence of long distance airborne spread of AD has been presented by Christensen et al. (1990) in Denmark. Gloster et al. (1984), in an investigation of 11 outbreaks of AD suggested that 7 out of 11 outbreaks of AD could have resulted from airborne spread.

MODIFIED ERADICATION PROGRAMME

The programme was modified on 1 January 1995 since AD virus circulation had ceased on all supplying farms and all pigs tested in the finishing herd over the previous 2 months had given negative results.

Breeding Stock Vaccination

All breeding stock were vaccinated 3 times per year.

Weaner Vaccination

Weaner vaccination on "problem" supplier farms, only; at 8 - 10 weeks of age and again on arrival in the fattening unit. All other weaners to remain unvaccinated.

Register of Approved Breeding Stock Suppliers

Purchase of breeding stock restricted to approved suppliers. Approved suppliers to blood test a minimum of 25 adult (or equivalent) breeding stock for AD in their herd at 6 monthly intervals, with negative results. A copy of the declaration, declaring clinical and serological freedom from aujeszky's disease to be furnished by the units veterinarian and the list of approved suppliers kept in the finishing unit.

Testing of AD Seropositive Units

AD seropositive units to submit colostrum samples from all sows of parity 5 or greater for the AD G1 antibody ELISA test. AD positive sows culled at weaning.

Testing of weaners

Random serological survey of weaners derived from all suppliers at 6 monthly intervals.

RESULTS

The results of clinical and serological tests would suggest that AD has been eradicated from the finishing unit. No seropositive pigs were identified on routine serological monitoring of slaughter pigs, subsequent to October 1994, a period of 4 months after the commencement of vaccination.

1. Circulating AD virus was eliminated from all supplying farms within 4 months of the date of commencement of vaccination.

2. A further serological survey of all supplying farms was conducted in January 1995 using the procedure described by Kavanagh (1994) where he reported that the AD serological status of sows could be determined by the simple and cost effective technique of blood sampling one of their

piglets. The time and effort involved in bloodsampling was reduced by bloodsampling 1 piglet per litter of selected lactating, random pregnant sows and replacement gilts. The survey results indicated that the number of AD seropositive sow units had been reduced from eight to four (Table 8).

Table 8. The prevalence of ad seropositive in suppliers in 1995.

	NO. FARMS	NO. POSITIVE
Sows	22	4
Weaners	22	0

3. Further serological monitoring of the four seropositive supplying farms was conducted in September 1995, as follows:

3.1 All adult breeding stock were bloodtested in herd one and the owner advised to cull the seropositives by April 1996.

3.2 Random testing of herd 2 and 3 (30 samples per herd) revealed that with the exception of one sample all animals of third parity or less gave negative results to the G1 antibody ELISA test. Based on the above results all sows of sixth parity or greater and those that gave a positive result on the G1 antibody ELISA test on colostrum, at weaning. Colostrum sampling was chosen instead of blood-sampling because it offers an alternative, cheap and practical method of ascertaining the AD status of sows (Bouwkamp, Stegman and Kimman, 1992).

THE COST OF AD IN A 12000 PLACE FINISHING UNIT

Key performance parameters were compared for the 9 month period November 1993 to July 1994, when AD was endemic, with a similar period from November 1994 to July 1995, when AD was absent from the herd. The results are summarised in Table 9.

Seasonal variations in pig performance were accounted for by examining similar periods in each year. No significant change took place in the number of suppliers, which changed from 23 to 22 during the periods under examination. The weight of pig at purchase remained unchanged, however the weight at sale was 5 kg higher in the second period than the first. Medication costs were similar in both periods when the variation in weight gain per pig sold was taken into account. No significant enteric disease problems were experienced, however, there was an upsurge in swine influenza incidence during the first period, which continued through the second period.

The number of pigs sold during the 2nd period was lower than in the first due to the increase in weight at sale. The 0.06 improvement in FCR yielded IR £0.33 per pig reduction in costs whilst the improvement in DLG from 602g to 622g contributed a further IR £0.23 per pig, cost reduction to give a total reduction of IR £0.46 per pig in production costs.

The estimated cost of AD on a per pig basis was 1p per kg gain, or 46p per pig. This is equivalent to a unit AD cost of IR £25000 per annum for the finishing unit. The monthly FCR figures were statistically analysed by the two sample T test. The changes recorded were not statistically significant.

Table 9. A comparison of unit performance before and after AD eradication

	Before	After
No sold	46,465	41,041
Sale wght (kg)	77.32	82.78
Purch wght (kg)	37.29	37.09
Wght gain (kg)	40.26	45.69
FCG (P) a	39.53	37.6
FCT (IR £) b	135.88	130.47
FCR c	2.94	2.88
FCD (kg) d	1.76	1.79
DLG (g) e	602	622
Mort %	1.21	1.28

If the above AD costings are extrapolated to the national herd of 160000 sows, of which 20% of herds were AD positive, 75% vaccinate (Lenihan 1994) and 5% have circulating virus (Kavanagh, 1995, unpublished data), then herds containing approximately 8,000 sows have circulating virus. The 170000 pigs produced by the above sows would therefore carry an AD cost of IR £85000 (£0.50 per pig). Vaccination of sows 3 times per year in 75% of herds would cost approximately IR £210000 (£1.75 per sow), giving an estimated cost of AD to the National herd of IR £300000 per annum. Since the estimated cost of AD to the Irish Pig Industry is relatively low, a national AD eradication programme should be designed, in conjunction with a cost/benefit analysis, taking into account the potential marketing advantages of an AD free national herd, changes in EU policy, and the current cost of AD to the pig industry. The projected duration of the programme should be clearly defined.

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REGIONALISED ERADICATION OF BOVINE VIRAL DIARRHOEA VIRUS IN SWEDEN - AN APPROACH COMPLEMENTARY TO THE CURRENT CONTROL SCHEME

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Bovine viral diarrhoea virus (BVDV), a pestivirus distributed worldwide, has during the last decade been identified as a source of considerable economic loss (Duffell et al., 1986). These losses have been estimated to be approximately £13 million per million calvings under Scandinavian conditions (Houe et al., 1993). In Sweden, a voluntary scheme to control the spread of the virus was started in 1993 (Alenius et al., 1994). The scheme is authorized by the Swedish Board of Agriculture, administered by the Swedish Association for Livestock Breeding and Production (SHS) and financed by subscribing farmers.

In July 1995, the Swedish Board of Agriculture decided to provide financial support for the control of BVDV, for activities complementary to the current control scheme. One major activity is the planning and implementation of intense eradication schemes in limited areas, called regionalized eradication projects (REP). This paper describes these projects and how they are integrated into the current control scheme.

BACKGROUND

Sweden has approximately 17,500 dairy herds and 17,000 beef herds. The average herd size ranges from 24 in the north to 38 in the south for dairy herds, and from 7 to 11 for beef herds. There are also approximately 7,500 rearing enterprises employing market purchased calves of 6-8 weeks age. The average cattle population density varies from approx. 100 cows per km^2 of grazed land in northern Sweden to 300 in the southern counties (Statistics Sweden, 1995). The annual replacement rate is, on an average, 35% for dairy herds and 25% for beef herds (SHS, 1995).

The housing season lasts from October-November to April-May in the southern parts of the country, whereas in the north, cattle are housed from August to June.

Veterinary and extension services

Veterinary services for farmers are maintained by state employed or private large animal practitioners, and veterinarians employed by the Regional Livestock Associations. The latter work mainly with herd health programs and investigation of herd health problems, whereas the former handle most clinical treatments and state veterinary work. All enrolment and herd investi-

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gations connected with the current disease eradication/control schemes on enzootic bovine leukosis and BVDV are made by these groups.

Extension services, including AI, are provided by the Regional Livestock Associations. AI-technicians do the major part of the sampling within the eradication/control schemes.

The control scheme on BVDV

The object of the control scheme is to establish and maintain dairy and beef cattle herds free from BVDV infection, and eventually, to eradicate the disease from the country (Alenius et al., 1994). Rearing units are not included in the scheme, since animals entering such farms are predestined for slaughter.

Farmers joining the scheme must follow rules concerning e.g. livestock trade, contact with animals from other herds and other ungulate species (i.e. sheep and goat). In order to be declared free from BVDV infection, a herd must be sampled twice, seven to eleven months apart, fulfilling one of the following criteria;

- undetectable/low level of BVDV antibodies in bulk milk samples,
- antibody negative pooled milk sample from 5-10 primiparous cows, or
- seronegative individual blood serum samples from 5-10 young stock over 15 months of age.

After a herd is declared free from infection, annual re-testing is made to confirm the status. In order to trade animals as coming from a certified BVDV-free herd, the latest re-test with approved result must have been made within the last three months.

The pace with which the scheme has been implemented in different areas has been a decision dependent on the Regional Livestock Association concerned. After 2 years (31 Dec. 1995) a total of 9,385 dairy herds (54%) and 2,253 beef herds (13%) had subscribed to the scheme. During the same period 6,247 (67%) of the dairy herds and 894 (40%) of the beef herds in the scheme were declared free from BVDV-infection.

The subscribing farmers finance all costs for sampling and analyses made within the scheme. Research, development and administration are also funded in this way. This is in contrast to the eradication scheme on enzootic bovine leukosis, which is financed by the state.

BVDV diagnostics and screenings

All diagnostics on BVDV are carried out by the National Veterinary Institute. For serology on serum and milk, an indirect ELISA (SVANOVA Biotech, Uppsala, Sweden) is used (Juntti et al., 1987, Niskanen et al., 1989, Niskanen, 1993). The immunoperoxidase technique according to Meyling (1984) is used for routine virus isolation. In an average week, the laboratory performs approximately 1,000 virusisolations and 3,000 serological assays.

National screening regarding the presence of antibodies to BVDV in bulk milk has been performed annually since 1993. On these occasions, all milk producing herds have been sampled. In addition, nineteen regional screenings were performed during 1991-1995. The results have been used to estimate prevalence of infected herds and annual incidence risks on the herd level.

WHY REGIONALISE?

In areas with a high herd density, a strategy based on totally voluntary participation and disease clearance has proved to be suboptimal. These areas correspond to those with high prevalence of BVDV-infection as well as high incidence risk. Farmers with BVDV-free herds are generally motivated to join the scheme. However, those with herds which have a long history of recurrent BVDV-infection can be hesitant towards a disease clearance, and also towards scheme participation. A major reason can be that these farmers regard the "closed herd concept", which is a part of the Rules and Regulations of the scheme, as unrealistic. In addition, they may run a higher risk of a setback after disease clearance, due to the high pressure of infection. A more realistic strategy is one where all infected herds are cleared from virus shedders during a shorter time period, and where control measures to prevent disease transmission are concurrently and consistently implemented in the whole area.

REP:s will also be performed in low prevalence areas, such as the northern parts of the country. At present, such areas are disrupted by "islands" of infected herds. Clearing these herds from virus shedders would be a minor task compared to the situation in high prevalence areas. The result would be a large continuous disease-free area, and a solid front against the disease.

Due to an increasing demand and a higher market value for animals from BVDV-free herds (SHS, 1996), farmers in areas that eradicate the infection at an early stage will have an advantage in the market. They will also be able to provide rearing units with BVDV-free calves. Such calves have been shown to have better growth and health during the rearing period (Alenius et al., 1996).

WHAT IS A REGION?

For the purposes of REP:s, a region is defined as any geographical area that is organisationally, geographically and/or epidemiologically homogenous, e.g. a regional livestock association area, an island/peninsula or a high prevalence area. The size of it will be limited only by the labour available to perform the field work. The only formal criteria that has to be fulfilled for any region is the ability to identify all herds in the area. This will be facilitated through herd registers used in the eradication scheme on enzootic bovine leukosis.

ACHIEVING COMPLETE PARTICIPATION

Although voluntary participation has been a most successful method so far, it is likely that other measures will have to be taken to eventually conclude the projects as well as the control scheme. At present, the Swedish Board of Agriculture has no plans to make the scheme compulsory. Fortunately, there is an increasing awareness of and focusing on quality and animal health issues in the farm industry. Many of the quality programmes presented by the beef and dairy industry include recommendations to farmers to join the control scheme on BVDV. Furthermore, the largest cooperative dairy organisation has recently taken a decision on compulsory participation in areas that become an object of regionalised eradication. By the end of June 1997, this demand will include all their milk suppliers, and there are strong indications that other dairy organisations will follow.

REP:s AND RISK MANAGEMENT

Planning REP:s began at the start of 1995. It was emphasized that great effort had to be put into preparing the ground for the factual implementation. Once an REP was to be started, all threats to its success must have been managed. A number of risk factors have been identified, both organisational and biological. In tables 1 and 2, those factors are listed which may have a highly detrimental effect on an REP *if* they occur. A "guesstimated" probability of occurence has been set to each factor, and their present and future management is described.

Table 1. Identification and management of risks associated with organizational circumstances when implementing a regionalized eradication project.

Risk	Probability	Management
Insufficient laboratory resources.	Low	• Laboratory staff involved in planning at early stage. • Thorough estimation of expected sample volumes.
Insufficient field resources (personnel) available for blood sampling.	Low	• Support from the board of the Regional Livestock Associations concerned. • Thorough estimation of expected number of visits and number of animals to sample.
Lack of interest in participation among farmers.	Low among present subscribers of the control scheme. Medium for most other farmers. High for a few.	• Unbiased and consistent information about the disease and reasons for, object and consequences of the project through suitable channels at an early stage. • "Marketing" of the concept. • Costs for analyses carried by the project to a great extent. • Support from the farm industry through demands upon or recommendations to suppliers to join the control scheme.
Internal conflicts in the field organisation.	Low-High	• No or insignificant problem in most areas. Existing antagonism *has* to be solved where present before initiating an REP.

As a part of the risk management process, a number of prerequisites have been stipulated. These have to be satisfied within a region before a decision to proceed can be taken. The prerequisites are presented to the board of the Regional Livestock Association concerned as a way of establishing realistic expectations and a uniform attitude towards proceeding. The prerequisites include;

- a well functioning collaboration between veterinarians working within the control scheme (and hence the REP).
- an expressed support for the project from the board(s) of the regional livestock association(s) concerned.
- support from the farm industry.

- functioning collaboration with livestock traders and routines for testing of animals passing through the livestock trade.

The Regional Livestock Association area covering the Island of Gotland functions as a pilot area for future REP:s. Their experiences have proved to be very valuable in the current planning of a more widespread implementation. It is clear that additional risk identification and managements regarding local conditions will have to be made in the beginning of each project, in collaboration with the person(s) regionally responsible.

Table 2. Identification and management of risks associated with biological phenomena when implementing a regionalised eradication project.

Risk	Probability	Management
Spread of disease through livestock trade and exhibitions.	High	• Information to livestock traders and transportation staff on how to prevent disease spread. • Facilitate trade of animals between certified BVDV free herds through making information about free herds easily available to livestock traders. • Individual testing of all animals traded from herds not declared free from BVDV, and collaboration on these issues between livestock traders and veterinarians. Isolation and re-testing of such animals before herd introduction required[a]. • A "no-trade policy" regarding pregnant animals with high titres adopted by several large livestock trading organizations. • Individual health certificates for all animals traded[a]. • No mixing of animals with different BVD status is allowed at auctions, exhibitions and during transportation[a]. • Livestock traders find it to be in their own interest to co-operate in the conclusion of the current eradication schemes, in order to simplify transportation and auction routines.
Spread of disease through animal contacts on pasture or similar.	Low-high (varies across the country)	• Systematic search for PI animals during the housing season in herds identified as having probable infection. • Recommendations to free herds to keep pregnant animals on pastures where the risk of disease transmission is minimised. • Recommendations on keeping untested animals (calves) off pasture in herds undergoing disease clearance. • Intentional contact with animals from herds with signs of infection or unknown BVD-status not allowed. Animals having unintentional contacts should be kept in isolation and tested twice before being reintroduced into the herd[a]. • Recommendations on double fencing to pastures of adjacent farms[a].

[a] Included in the Rules and Regulations of the current control scheme on BVDV.

Table 2, cont.

Risk	Probability	Management
Spread of disease through visitors including vets, AI technicians and herdsmen in the replacement system.	Low	• Increase awareness about prevention of disease transmission among veterinarians and other occupational groups with ambulatory services to farmers through education and information. • Recommendations to provide visitors with boots and coats/overalls to borrow, or to have troughs/trays for boot desinfection available[a].
Spread of disease through transportation vehicles in connection with on-farm collection of slaughter animals or brokered calves.	Medium	• Recommendations to farmers to have pick-up and delivery points outside cattle accommodations[a]. • Recommendations from employers of transportation staff to their personnel not to enter cattle accommodations in order to avoid transmission of disease. • Directions regarding cleaning and desinfection of transport vehicles adopted by livestock transportation personnel.
Spread of disease through other species (sheep, goats, deer, elks).	Low	• Sheep and goats entering cattle farms must be tested free from BDV. An isolation period of 4 weeks is recommended[a]. Exception is made for sheep/goats from BVDV-free farms. • No evidence exists of wild ungulates acting as a major source of infection, even though interspecies transmission is possible (Nettleton, 1990).
Spread of disease through vectors (ticks,mosquitos, flies).	Low	• Insects, such as biting flies have been shown to be capable of transmitting BVDV under experimental conditions (Tarry et al., 1991). However, this route of infection has never been described under natural conditions.

[a] Included in the Rules and Regulations of the current control scheme on BVDV.

IMPLEMENTATION

A regionalised eradication project consists of six parts;

- resource estimation,
- information,
- enrolment,
- identification,
- eradication,
- surveillance.

The aim of an REP is to remove all cattle persistently infected (PI) with BVDV and thus to have no new infections within 2 years. The infection should be considered as eradicated within 3 years from the end of the identification phase. Furthermore, all herds within the region should be enrolled in the control scheme.

Resource estimation

In order to calculate the amount of labour and laboratory resources required, the number of herds that will have to undergo different types of measures has to be estimated on a time scale. In some areas, many herds will already be in the scheme, and their BVDV status is known. For remaining herds, certain assumptions have to be made in order to estimate the number of samples to be collected and seroassays/virus isolations to be performed. These are based on present knowledge, such as the relationship between bulk milk screenings/control scheme testing procedures and true prevalence, and experience of within-herd seroprevalence at herd screenings. All assumptions are continuously revised.

Plans are made in collaboration with the person(s) regionally responsible for the project, and estimated sampling volumes are checked with the National Veterinary Institute. The result is a detailed project document. Monthly checks will be made in order to take immediate measures if the project does not proceed according to plan.

Information

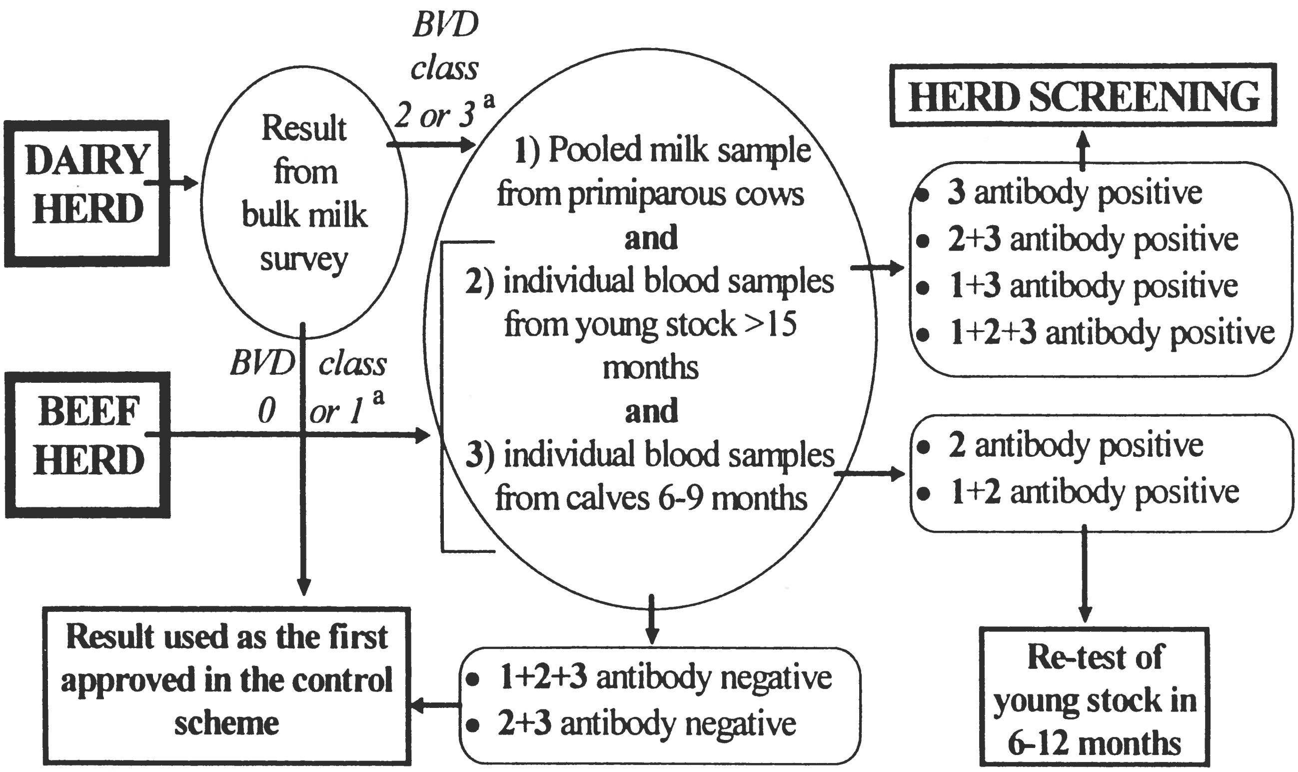
One factor considered as having a great impact on the result of an REP is the presentation of the project in the area. A general information strategy is being worked out, which contains elements of education, information and marketing. The aim is that everyone affected by the project - farmers, livestock traders, AI-technicians, extension personnel, veterinarians, transportation staff etc. should know the purpose, object and time perspective of the project, their own role in it, and how it will affect them. Regular feedback on how the project is progressing will be given through suitable channels.

Enrolment

Enrolment is an essential part of an REP. Once a project is concluded, comprehensive participation in the scheme will constitute the basis for surveillance and for sustainment of free areas. It is also important from an educational point of view. In joining the scheme, farmers receive information about the Rules and Regulations which are in general for protection against any transmissible disease. Enrolment activities will start at the same time as the identification phase and continue until all herds are in the scheme. One way to save time and labour during REP:s is to educate, inform and enrol farmers at one-day meetings instead of at on-farm visits, which at present are more common.

Identification

The purpose of the identification phase is to determine which herds need further investigation, and specifically which herds will have to undergo disease clearance. It also points out which herds can be entered into the regular testing of the control scheme, in order to be declared free from BVDV. On the whole, the steps taken during the identification phase mainly follow the same flow chart as the control scheme, but they are performed in a more time-efficent manner. The flow chart for an REP identification phase is shown in fig. 1.



[a] Categories used in the current control scheme to classify herds according to BVD status. Class 0 and 1 reflects an undetectable/low level, and class 2 and 3 reflects a moderate/high level of antibodies in bulk milk.

Figure 1. Testing procedure applied in the identification phase of a regionalized eradication project.

Eradication

All herds identified as having probable infection become objects of an investigation aimed at identifying and removing all PI animals (Larsson et al., 1994). The procedure is described below, in chronological order.

Primary herd screening: All animals over 10 weeks old are sampled concurrently and tested for antibodies to BVDV. In addition, virus isolation is attempted on all samples from seronegative animals. All virus positive animals are removed.

Follow-up visits: All calves born are sampled after reaching 10 weeks of age, during approximately one year after the primary herd screening. The analyses described above are performed. Virus positive animals are removed. Eventually, any dams that were seronegative in the primary screening are re-tested. If any seroconversions have occurred, the offspring are tested for the presence of antibodies/virus.

Start or resumption of control scheme surveillance: A herd that has been cleared from the infection will be transferred to control scheme surveillance as soon as it can produce a sample of seronegative individual blood serum samples from young stock over 15 months of age.

The identification as well as the eradication phase require the handling of young stock. To facilitate this, all sampling up to and including the primary herd screenings will have to be finished during the housing season. The aim is to determine the BVDV-status of all stock before they are let out. This is to assure, as far as possible, the absence of PI animals on pasture.

In herds free from infection, especially those who have to use unattended pastures or are at high risk of unintentional contacts at pasture, recommendations are given to keep pregnant animals in fields that would minimize the potential contacts with infected animals.

Surveillance

Bi-annual bulk milk surveillance will be performed on all milk producing herds in the region. Its main purpose will be to provide a baseline to evaluate how the control measures taken affect incidence risk and prevalence of herds with probable infection in the area. This method can also, to a great extent, be used to pin-point new cases of infection. No comparable surveillance data are available for beef herds.

Surveillance will also be carried out through the regular testing made within the control scheme. This method will include an increasing number of herds as the enrolment progresses. The method used will depend on type of production (dairy/beef) and, for dairy herds, the most suitable sampling method (bulk milk/pooled milk/individual samples). The surveillance within the scheme is primarily aimed at discovering new cases of infection.

In fig. 2, a conceivable time schedule for the implementation in dairy herds is shown.

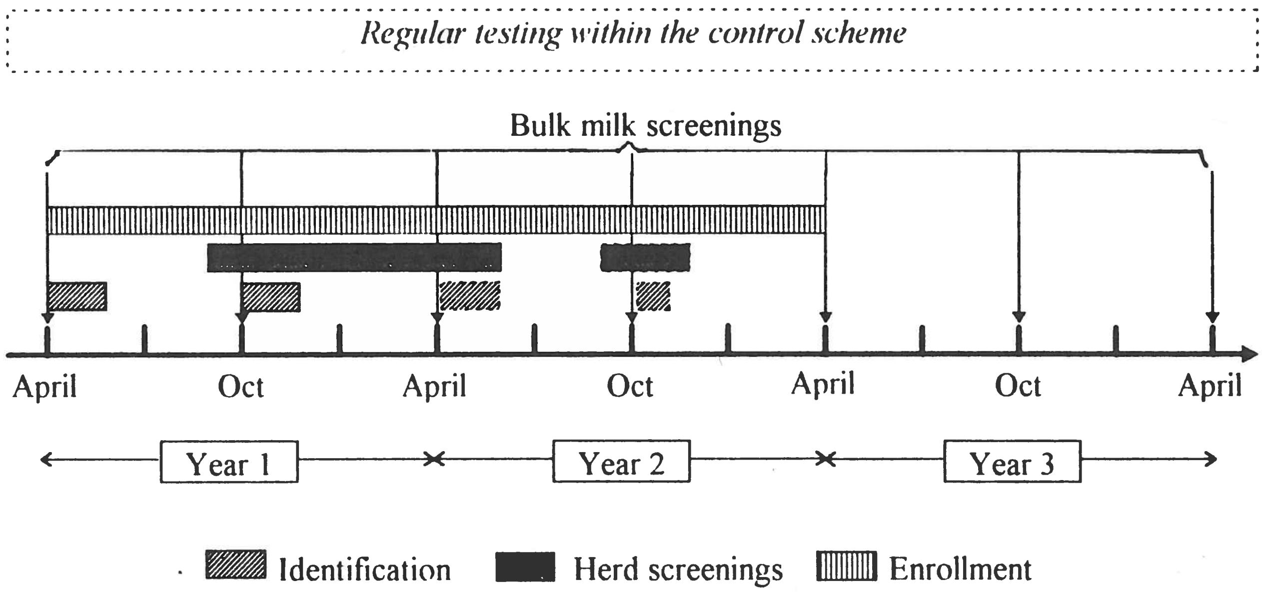


Figure 2. General time plan for the field work in dairy herds during REP implementation.

FINANCING

In high prevalence areas SHS has, as a standard, budgeted £150 per herd to cover the farmers' costs for analyses of samples during the identification and eradication phases, up to and including the primary herd screenings. A herd screening is usually an economically cumbersome item, and a possible reason for hesitation regarding disease clearance. The project also pays for bi-annual bulk milk surveillance. The farmer has to pay for labour and, in herds undergoing disease clearance, also for analyses made during a one-year follow-up of calves born. Those expenses are estimated to be, on an average, £400 for dairy farmers and £150 for beef farmers.

HANDLING FARMS IN FREE AREAS AND BORDER ZONES

Since REP:s are not imposed by any law or decree, no formal possibility exists for the establishment of border zones with special restrictions, or for the declaration of areas officially free from BVDV infection. However, after eradicating the disease from a region, a demand to test imports would be a important way of reducing the risk of reintroducing the infection. Such a demand, if imposed by the government, would constitute a trade restriction. However, if introduction of animals from herds not declared free from BVDV is to be made into a free area, demands for testing and certification will be made by the farmers, in view of the scheme - and not by the state. In border zones, more intense surveillance will be needed. The possibilty of re-testing with a shorter interval than generally stated by the scheme can then be considered.

SUMMARY

Organized control of BVDV in Sweden has been performed on a voluntary basis since 1993. The option to intensify the measures through systematic eradication in limited areas arose during 1995. For the eradication to be successful, dialogues with representatives from the farm industry, including livestock traders, have been initiated at an early stage, and substantial effort will have to be put into education and information. The eradication projects would apply testing procedures and methods previously used in the control scheme, as recommended for clearance of herds from virus shedders and for surveillance. Comprehensive participation in the scheme is regarded as an important prerequisite for future sustainment of free areas.

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QUANTITATIVE RISK ASSESSMENT OF MEAT-BORNE BIOLOGICAL HAZARDS TO PUBLIC HEALTH: PROGRESS AND PROBLEMS

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During 1995, we undertook a study for the Meat Hygiene Division (MHD) of the Ministry of Agriculture, Fisheries and Food (MAFF) on the feasibility of using a risk assessment approach to determine the risk to public health from biological hazards in red meat. Several events have stimulated research in this area (Hathaway, 1993).

The desire of governments worldwide to reduce spending and to transfer the cost of assuring food safety to industry has led to increased questioning of the value of various regulatory requirements for food safety. In the meat area, traditional organoleptic inspection procedures have come under particular scrutiny with the recognition that the most important hazards to public health are microorganisms from healthy or subclinically infected animals, for example, *Salmonella* and *E. coli* O157:H7 (National Research Council, 1985). Risk analysis provides a tool to assess the risks and benefits of procedures to assure the safety of meat and to support policy and managerial decisions in the meat hygiene area.

In order to produce microbiologically safe food, increasing use is being made of the Hazard Analysis and Critical Control Point (HACCP) system (Baird-Parker, 1994). A HACCP system for meat involves assessing the hazards and risks associated with meat at each step of the food chain, identifying the critical points necessary to prevent or control the identified hazards, monitoring these points and taking corrective action if necessary (National Research Council, 1985). Hence, risk assessment is the essential first step in the HACCP system.

Under the Agreement on Sanitary and Phytosanitary (SPS) measures adopted as part of the General Agreement on Tariffs and Trade in 1994, member states are required to base their food safety and animal and plant health regulations on international standards wherever possible (Scudamore, 1995). However, countries may maintain a higher standard of protection than the international standard if, using risk assessment techniques, they can demonstrate that there is scientific justification for their decision. The European Union uses a similar set of principles to avoid disparities that could affect internal trade and to assure the same level of protection throughout the European Union (Gardner, 1995).

Finally, risk assessment is seen as an ideal way of making the basis of regulatory decisions about food safety transparent to consumer groups. It is hoped that well-presented risk assessments will help to change public perceptions about the nature of food safety risks.

This paper reviews progress in quantitative risk assessment (QRA) of foodborne microbiological hazards, describes problems associated with applying the technique to pathogens in meat and presents some preliminary thoughts on methods for assessing the risk to public health from meat-borne biological hazards.

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HEALTH RISK ASSESSMENT

Health risk assessment came of age in 1983 with the development by the United States National Academy of Sciences (NAS) of a conceptual framework for determining the risk to public health from chemical hazards (National Research Council, 1983). The NAS defined risk assessment as "the qualitative or quantitative characterisation of the potential health effects of particular substances on individuals or populations" and risk management as "the process of evaluating alternative regulatory options and selecting among them".

The NAS risk assessment model comprises four steps:

1. Hazard identification: Determination of whether a particular agent or substance is or is not causally linked to particular human health effects.

2. Dose-response assessment (hazard characterisation): Determination of the relation between the magnitude of exposure and the probability of occurrence of possible health effects.

3. Exposure assessment: Determination of the extent of human exposure before or after application of regulatory controls.

4. Risk characterisation: Description of the nature and magnitude of human risk including attendant uncertainty.

As a description of the general risk assessment process is being given by other researchers from this department in another paper at this conference (Wooldridge, pers. comm.), we will move directly to the risk assessment of hazards in food.

QUANTITATIVE RISK ASSESSMENT OF FOODS

Chemical risk assessment

Risk assessment is relatively well developed for chemical hazards in food (Lu & Sielken, 1991; Hathaway, 1993). The safety of food additives and chemicals for humans are assessed largely by toxicological studies in experimental animals. From these studies, the dose of a substance at which there are no statistically significant increases in the frequency or severity of adverse effects between the treated and control groups of animals is established. This dose is termed the no-observed-effect-level (NOEL).

The NOEL of a substance usually is divided by a safety factor to compensate for uncertainties in the scientific process and this "safe" dose is established as the acceptable daily intake (ADI) for that substance in humans. An ADI is not strictly a quantitative measure of risk of a chemical hazard in humans but the end-point of a process designed to set limits for chemical hazards in food without having to determine an acceptable level of risk.

For chemicals applied to agricultural produce or food animals, potential maximum residue levels (MRLs) are calculated from the ADIs and assumptions about dietary intake. From use of the chemicals or drugs according to good agricultural or veterinary practice, likely residue levels in produce or animal tissues can be determined and these MRLs are compared with the potential MRLs derived from ADIs. If the residue level from the use of a chemical is lower than its potential MRL, the recommended MRL is reduced. If the reverse is found, the risk management decision may be to ban the chemical, set a withdrawal period for it or, on the balance of benefits and costs, to accept an MRL above the potential MRL.

Microbiological risk assessment

Risk assessment of biological hazards in food is more complex than that of chemical hazards. The difficulties involved in the quantitative estimation of the risk to public health from biological agents in food have been described by Skinner (1992) and Hathaway (1993). Briefly, the development of risk assessment models for pathogenic organisms in food has been complicated by

- ability of organisms to multiply, interact and/or die as they traverse the food chain,
- transmissibility of organisms and the capacity for secondary spread of foodborne pathogens,
- variability in virulence of strains of organisms,
- human and animal carrier states, long incubation periods and persistent shedding of some organisms,
- variation in susceptibility of different segments of the population to pathogens, for example, by age, immune status, health status and pregnancy,
- variation in frequency of potential exposure to different pathogens,
- use of various control strategies, for example, vaccination, hygiene,
- persistence of organisms in the environment including food,
- range of foods in which contamination can occur,
- uneven distribution of pathogens in food,
- interaction of organisms with host and environment, which is complex and specific to each pathogen,
- lack of data, especially human dose-response data.

Because of the complexity of the subject, there has been little application of QRA techniques to the microbiological safety of food. QRA models have been developed for microbiological hazards in drinking water (Regli *et al.*, 1991; Rose & Gerba, 1991; Rose *et al.*, 1991; Haas *et al.*, 1993), reclaimed wastewater (Rose & Gerba, 1990) and shellfish (Rose & Sobsey, 1993). These researchers are also working on a QRA of *Salmonella* and *E. coli* in food.

Risk assessment of biological hazards in meat

The components of a QRA of microbiological hazards in meat have been described in broad terms (Albanese, 1992; Covello & Merkhofer, 1993; Hathaway, 1993) but we are not aware of any comprehensive quantitative assessments of the risk to public health from specific biological hazards in meat. In the next section, we look at what such studies would involve.

MICROBIOLOGICAL RISK ASSESSMENT OF MEAT

Definition of risk

In the project that we undertook for the MHD, one of the objectives was to quantify the risk to human health from biological hazards in red meat. This does not sound too difficult until one attempts to define in quantitative terms exactly what one is trying to measure.

Risk is defined as a function of the probability of an adverse event and the magnitude of that event. Therefore, the end-point of a risk assessment of a biological hazard in red meat is some quantitative measure of the probability of an adverse health effect in the human population due to exposure to the hazard in red meat. Risk may be expressed on an individual food serving basis (Rose & Sobsey, 1993), for example, the probability of an individual becoming ill from consuming a single serving of red meat. Alternatively, risk may be defined on a population basis as the expected number of people becoming ill from exposure to the pathogen in red meat over the course of a year.

Defining adverse effects

As a pathogen may cause a range of adverse health effects in humans, a series of measurements may be required to quantify the risk caused by a hazard. Adverse health effects may be defined in broad terms, such as illness and death, or as specific syndromes such as gastroenteritis, or in terms of the consequences of exposure, for example, hospitalisation. The adverse effects of a microbiological hazard in food may not be confined to human health. Organisms in meat may present a risk to animal health, so this should be considered in a risk assessment of the safety of imported meat.

When choosing an endpoint for a health risk assessment, care should be taken to distinguish between exposure, infection and disease (Skinner, 1992). As a person may be infected with an organism but experience no adverse health effects, a risk assessment based on infection rates will give a higher estimate of risk than one based on morbidity rates. On the other hand, a healthy infected person may transmit the disease to others, a factor that is of consequence in the estimation of risk.

Probability of an adverse effect

Cause-specific infection rates, morbidity rates and mortality rates may be obtained as part of a country's routine disease surveillance activities or from surveys. They usually are expressed as the number of people affected each year per 100,000 population. Case-fatality rates calculated from outbreaks of foodborne disease can be used to estimate the number of deaths attributable to a particular pathogen.

Risk of an adverse effect attributable to a hazard from a specified source

If the only source of a pathogen for humans was red meat, then the risk to human health from the pathogen in red meat would be equivalent to the number of human cases of the disease occurring each year in the population of interest. One example is the beef tapeworm, *Taenia saginata*. Humans become infected with the tapeworm by eating beef containing viable cysts of the parasite (*Cysticercus bovis*). As there are no other routes of transmission of *T. saginata* between cattle and humans, the incidence of infection in humans is a measure of the risk of becoming infected with the parasite through ingestion of red meat.

Unfortunately for most pathogens that may be transmitted from animals to humans through the consumption of meat, there are many other sources of the pathogen for humans. Therefore, one is faced with attempting to estimate that component of the risk that may be attributed to the pathogen in red meat, or whatever source is of interest. We considered three approaches to estimating the risk of adverse effects attributable to exposure to a biological hazard from a specified source such as red meat.

<u>Foodborne disease surveillance</u>

Surveillance data on reported outbreaks of foodborne diseases and any suspected food vehicles are collated by national public health authorities (Anon, 1990). These data give an indication of the relative importance of different foods as vehicles of transmission of various organisms but have limited usefulness for determining the true incidence of foodborne disease attributable to specific foods. This is because most cases of foodborne disease are not reported and for those that are, a specific food source is rarely identified.

<u>Epidemiological studies</u>

Appropriately designed epidemiological studies on the association between red meat consumption and the occurrence of human disease could be used to estimate attributable risk. The population attributable rate provides a direct estimate of the rate of disease in a population attributable to the factor, for example, consumption of red meat. The population attributable fraction measures the proportion of disease that is attributable to the factor. These measures can be used to estimate the maximum reduction of disease frequency that might be expected if the exposure factor was removed from the population. A discussion of attributable rates and their formulas is given by Martin *et al.* (1987).

We did not pursue the epidemiological study approach in any depth mainly because the information provided by such studies would probably not be sufficient to measure the impact of changes in meat hygiene practices on human health. This was an important aim of the risk assessment of biological hazards in red meat.

<u>Modelling approach</u>

The third approach follows pathogens from the beginning of the food chain to disease in the consumer rather than working backwards from cases of foodborne disease to the food source. Mathematical modelling techniques are used to estimate the likelihood of contamination of red meat by a pathogen at various points along the food chain, the probability of significant exposure to the consumer and the risk of disease in the population. This approach is implicit in the NAS framework and has been applied to a risk assessment of viruses in shellfish (Rose & Sobsey, 1993). We concentrated on this method as it seemed the best approach to elucidate the relationship between microbiological contamination in the slaughterhouse and the frequency of foodborne diseases in the human population.

APPLICATION OF THE MODELLING APPROACH TO BIOLOGICAL HAZARDS IN MEAT

Hazard identification

The first step in the NAS risk assessment model is hazard identification, which is the qualitative indication that a substance or agent may adversely affect human health. Risk assessments of chemical agents generally start with a chemical whose effects on human health are unclear. In the case of biological hazards, we usually are aware of which organisms are potentially pathogenic for humans and are more concerned about whether a particular food or food situation is a source of the organism for humans.

In the study for the MHD, we sought to identify microorganisms and parasites found in slaughter cattle and sheep, which may have an adverse effect on human health and which may be transmitted to humans by ingestion of, or contact with, red meat. We defined "red meat" as any processed or unprocessed tissue derived from cattle or sheep.

Two relationships were of interest. The first was the potential of various organisms found in slaughter cattle and sheep to cause disease in humans. This is an area that is being revolutionised by molecular techniques for detecting and characterising microorganisms. New techniques for detecting microorganisms mean that the list of known foodborne pathogens is likely to grow while genetic typing of organisms is challenging established theories about host-parasite relationships. These developments make hazard identification a moving target. It is difficult to know at what taxonomic level to conduct a risk assessment. Ideally if only particular strains of a meat-borne organism are pathogenic for humans, the risk assessment should be confined to those strains but data at a subspecies level are likely to be sparse.

The second relationship was the potential of red meat to serve as a vehicle for the transmission of a pathogen from cattle or sheep to humans. If there was no evidence for the transmission of a zoonotic organism to humans through the consumption of red meat, we did not consider it for a QRA. This meant that we were implicitly assigning a zero risk to some zoonotic pathogens found in livestock, for example, leptospires. In other cases, we were ignoring the role played by red meat in perpetuating the life cycle of a zoonotic pathogen, for example, hydatid disease. We did this to reduce the study to a manageable size. However, it may be more appropriate to consider the route of transmission of a known zoonotic pathogen as part of the exposure assessment. That way the role of a foodstuff in the transmission of a pathogen from animals to humans is made explicit and the risk is judged more accurately.

Hazard characterisation and exposure assessment

The second and third steps in the NAS model involve the quantification of the risk to human health caused by exposure to a hazardous substance or agent. The objective is to estimate the probability of an adverse health effect occurring in the population from knowledge about the dose-response relationship and the level of exposure to the substance or agent in the population.

Dose-response relationship (hazard characterisation)

For chemical hazards, the dose-response relationship is determined using experimental studies in animals and extrapolating the results to humans. As the pathogenicity of organisms differs among species, this approach cannot be used to estimate dose-response relationships for pathogens in humans. The alternative is to conduct feeding studies on human volunteers but such studies are limited because of ethical considerations. They also tend to be conducted on healthy adults using laboratory cultures, so the results may not be representative of the general population. Individual susceptibility to microorganisms varies with such factors as age, immunity, health status and pregnancy while the infectivity of an organism for humans can be affected by the food in which it occurs and the way it is ingested.

To overcome the lack of human experimental data, infective doses of microorganisms may be inferred from levels found in foods associated with disease outbreaks (Blaser & Newman, 1982; Willshaw *et al.*, 1994). Another approach was taken by Martin *et al.* (1995). They asked experts in foodborne diseases to make judgements about the risk of illness and its severity in different population groups at various doses of each pathogen based on knowledge of human dose-response studies, foods commonly infected and pathogen concentrations in violative foods including levels associated with outbreaks of disease. While these methods cannot substitute for scientifically established dose-response relationships, they do provide sufficient information to enable the risk assessment to proceed albeit with qualifications.

To estimate the risk of infection or disease at various doses of microorganisms, mathematical models are used to describe the experimental dose-response data. This is an important part of a QRA because the type of model fitted to the dose-response data may affect the risk estimates. Haas (1983) evaluated three models for their ability to describe experimental dose-response data for human exposure to waterborne microorganisms. These models were related to theories on the process of infection with microorganisms.

Exposure assessment

To estimate the probability of significant exposure to a pathogen in meat, we need data on consumption levels of meat, rates of contamination of meat with the organism and the rate of secondary spread of the pathogen in the human population.

Food consumption data: To estimate exposure of a population to a chemical hazard in food, per capita consumption data are often used (Lu & Sielken, 1991). This approach is useful for hazards whose effect is cumulative but is less applicable to microbiological hazards in food where a single exposure to a pathogen can have an adverse health effect (Rose & Sobsey, 1993). To assess exposure to microbiological hazards in meat, data are required on the average serving of meat consumed at a sitting and the frequency of consumption of meat in the population. As the risk of foodborne disease is influenced by the type of meat product consumed, a breakdown of meat intake by product type is important, for example, cut meat, sausages, minced meat.

The main source of information on food consumption in the UK is the National Food Survey. Every year a sample of households records every item of food brought into the home for consumption. This survey provides a breakdown of per capita consumption of meat by product type (MAFF, 1994).

The National Diet and Nutrition Survey is a more ambitious attempt to assess individual food intakes in Britain by age, sex and social class (Gregory *et al.*, 1990; White & Davies, 1994). These features of the survey will make it particularly valuable for risk assessment studies as a major criticism of such studies is their failure to take account of those groups in the population who are likely to be more susceptible to a particular hazard or who consume higher quantities of a particular food.

The form in which food is consumed may have a considerable impact on the risk of foodborne disease. Undercooked meat is commonly implicated in cases of food poisoning. Therefore, knowledge of the proportion of the population preferentially consuming meat in this state and the frequency with which they consume it may allow more precise estimates of the risk of contracting meat-borne infections. To obtain this type of data, market surveys of people's eating habits are required.

Contamination levels of meat with pathogens: The level of contamination of a food just before consumption is the best predictor of the probability of human disease. However, as it is virtually impossible to know the microbiological load of a food at the point of consumption, it must be estimated. For veterinarians and others interested in the effect of contamination levels in animals and carcasses on human health, this means modelling the fate of microorganisms from source to consumption based on knowledge of average contamination levels of the product at critical points, the conditions to which the product is likely to be subjected and the effect of those conditions on the microbiological load of the product.

With the assistance of colleagues in the Veterinary Laboratories Agency, we reviewed the published literature on infection rates in slaughter cattle and sheep and the levels of contamination of cattle and sheep carcasses and retail red meats with biological hazards in the UK. For many pathogens, we could find no recent data. In general, it appeared that the longer a species had been recognised as a source of foodborne disease, the older the survey data. However, while the paucity of data is a setback to a QRA of biological hazards in meat, it is a situation that can be remedied either through collection of the appropriate data or by using the risk assessment process itself to evaluate the impact of a range of contamination levels.

More difficult is how to relate contamination levels in carcasses to levels at retail or consumption when carcasses may end up in many different meat products and when organisms are not uniformly distributed throughout a carcass and subsequent meat products. It is perhaps instructive that to date, QRA of microbiological hazards has been applied mainly to pathogens in water, a medium in which they can be assumed to be uniformly distributed and dispensed to the consumer.

Conditions to which meat is exposed along the food chain: The exposure of the human population to pathogens in meat depends, among other things, on the conditions to which meat is subjected from slaughter to consumption. If it is assumed that the various regulations governing meat hygiene are adequately enforced, then the standards specified in these regulations may be used to define the conditions to which meat is subjected from slaughter to retail sale. To determine the conditions to which meat is subjected after it is sold to the consumer but before it is consumed, surveys of how food is handled in the home may provide useful information (MAFF, 1988; Evans *et al.*, 1991).

As the differences between how meat should be processed, stored and handled and how it is actually treated may be quite large, a risk assessment of microbiological hazards in meat should make explicit the exposure scenarios being modelled. In many cases, the construction of a series of exposure scenarios will be required to take account of the risks presented by different meat products and situations. Outbreaks of foodborne disease often occur from inadvertent breakdowns in process control and the handling of food, so thought should be given to simulating randomly occurring events in an exposure assessment.

Predictive modelling of microorganisms: Using experimental data on the effect of physical factors on the survival and growth of microorganisms, mathematical models have been developed to predict the fate of microorganisms in food under different conditions (Buchanan, 1992). Such models constitute an important building block in an exposure assessment of microbiological hazards in food.

In the UK, MAFF has funded the development of a model to predict the growth of foodborne pathogens under different conditions of temperature, pH, salt concentration and other relevant factors. The set of models is available as a computer program called Food MicroModel® (Food MicroModel, 1994) and as it covers several meat-borne pathogens, its use in a QRA of these pathogens in meat should be explored.

Secondary transmission: Person-to-person spread of a foodborne disease may be quantified by observing the number of cases of illness per foodborne incident and the number of non-food associated cases. This information may be extracted from reports of foodborne disease outbreaks in the medical literature.

Risk characterisation

Risk characterisation is the last step in the NAS framework. It involves the presentation of the final risk measures together with a summary of the biological and statistical uncertainties revealed in the course of the risk assessment. Limitations of the data and the process are also described.

DISCUSSION

The need for changes in meat inspection procedures to assure the microbiological safety of meat has been recognised for at least a decade (National Research Council, 1985). However, the means by which microbiological safety can be improved continues to be the subject of debate (Berends *et al.*, 1993). Experts differ on where in the meat food chain to intervene and on how to validate the microbiological quality of meat. In an attempt to resolve these issues, much technical information has been generated.

There has been considerable research, for example, on the contribution that various procedures within the slaughterhouse make to the contamination of carcasses (Roberts & Hudson, 1987). The objective is to identify the critical control points at which microbiological contamination of meat may best be controlled in the slaughterhouse. Similar research has been carried out at all points in the meat food chain although it is sparse for the farm and the home. What is missing is a pulling together of all the technical data to develop a cost-effective approach to assuring the microbiological safety of meat for consumers from "farm to fork".

The raison d'être of a risk assessment is to provide information to decision makers to enable them to allocate resources to those food safety activities that provide the greatest return on investment in terms of improved human health. To determine whether the allocation of resources is optimal, the results of a risk assessment have to be put into a risk evaluation or economic framework utilising such methodologies as cost-benefit analysis, cost-effectiveness analysis and decision analysis. Failure to do this could lead to the adoption of risk reducing procedures whose cost outweighs the benefit in terms of improved public health.

Quantitative risk assessment techniques offer a valuable tool to assess the effect on human health of measures to reduce the contamination of raw meat with biological hazards. The approach could be used to evaluate control procedures at farm and abattoir level in the context of the whole food chain or within the production and processing environment. The use to be made of the information will dictate the boundaries of the studies. Along the way, we will encounter methodological problems and find that much of the data needed to obtain accurate estimates of risk are not available. However, solutions will come as researchers attempt to apply QRA techniques to specific biological hazards in meat.

Quantitative risk assessment of biological hazards in meat is at much the same stage of development that cost-benefit analysis of animal disease control programmes was in the late 1960s. Researchers recognised a valuable decision-making tool but it took over a decade of endeavour to arrive at a consensus on how the technique should be applied in the animal health area. If risk assessment is to serve as a basis for acceptance by trading partners of each other's food safety standards as set out in the SPS Agreement, then a similar concentration of effort will be required to reach agreement on the proper criteria and methods for conducting microbiological risk assessments of meat and other foods.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support received from MAFF for this project and the contributions of various colleagues in the Veterinary Laboratories Agency.

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GIS MAPPING OF EXPECTED *Vibrio Vulnificus* LEVELS IN SOUTHERN LOUISIANA OYSTERBAYS

MARTIN HUGH-JONES, KRAUSE WILSON, & SCOTT SCHEFFLER

Louisiana has a wide range of endemic *Vibrio* species — *V.alginolyticus*, *V.cholerae* (non-01, and 01-toxigenic & non-toxigenic strains), *V.damsela*, *V.fluvialis*, *V.mimicus*, *V.paraheamolyticus* — that can be found in the coastal waters and oysterbays. *V.cholerae* is a most interesting organism to study but difficult to recover from these or any other endemic waters. For obvious reasons one also does not advertise its availability. To date we have had no deaths from it. So we are attacking it sideways by using a *V.vulnificus* model, initially mathematically but later by from environmental sampling and modelling. The US/FDA is more concerned with the few *V.vulnificus* deaths and it is easier to obtain funding to investigate these deaths. The consumption of raw oysters is commonly associated with incidents of human diarrhea thanks to these various endemic *Vibrio* species. The pre-existing environmental data, oysterbay water quality data, relates epidemiologically to *V.vulnificus* high risk sites; *V.cholerae* is associated with less saline water 'upstream' of the oysterbays and crabs.

Since its first report in 1978 until 1994 Louisiana has had 52 cases of endemic cholera reported due to the Gulf Coast toxigenic strain of the *Vibrio cholerae* 01, El Tor biotype/Inaba serotype, characterised by a specific vibriophage VcA-3. It is a strain unique to the Gulf Coast (Almeida et al, 1992; Chen et al, 1991; Goldberg & Murphy, 1985; Wachsmuth et al 1993). The incidence of reported cases is variable with no cases reported in 8 out of 17 years. Onset was from June to November but over 90% were in August & September. At this time outbreak years appear to have had less seasonal rain than the report-free years. There was no significant sex difference though 1.3 males were affected for each female. All ages were affected equally. The distribution of cases usually ranged from 1-5 reported cases; 17 places had only 1-2 cases but a single outbreak at Dry Creek involved 13 persons over six days. The large outbreak in Dry Creek was probably due to a social crab boil as they were all men, aged 19 to 42, and 11 out of 13 had onsets within a period of 48 hours. It is notable how the distribution is essentially south of Hwy I-10 and near to the Gulf Coast marshes (MacFarland, 1993).

Until recently all *V.cholerae* 01 isolates from the US Gulf states have been of the Gulf Coast strain (Blake, 1993). However, the Peruvian strain was isolated from oysters and fish intestinal contents collected in Mobile Bay, Alabama, during July and September, 1991, but has not been reported since; the origin appears to have been ballast water in cargo ships coming from ports in South America (Depaola et al, 1992; McCarthy et al, 1992). Retrospective investigations of outbreaks in 1978 (Blake et al, 1980), 1986 (Lowry et al, 1989), and 1989 (Geregatz &

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MacFarland, 1989) indicated that blue crabs were the major risk, especially when boiled for less than nine minutes or steamed for less than 30 minutes; shrimps and oysters were also implicated but at a lower risk level. The single instance of cholera from crabs shipped interstate was in 1984 from Texas crabs consumed in a Maryland restaurant (Lin et al, 1986). The same strain has been isolated from raw Louisiana oysters (Klontz et al, 1987), from red swamp crawfish (Thune, Hawke & Seibling, 1991), and from cooked rice rinsed in water contaminated by the index case on an oil rig (Johnston et al, 1983).

Raw oysters shipped interstate resulted in reports of single cases in 1986 from Texas oysters (Pavia et al, 1987) and from Louisiana oysters (Klontz et al, 1987), and in 1988 of six cases in six separate states over a period of 55 days (CDC, 1989). It is interesting to note that in 1986 there were 18 cholera cases reported in Louisiana with crabs as the major risk. But the number of cholera cases due to oysters, *Crassostrea virginica*, is not a function of Louisiana oyster production, which averaged 12.6 million pounds annually for the period 1980-88 and represented 55% (by 1988 81%) of the production from the Gulf and 26% (latterly 42%) of the national production (Berrigan et al, 1991). Oysters are epidemiologically less important in spite of the comments of medical authorities that "eating oysters in New Orleans or going on pilgrimage to Mecca" were high-risk activities (Morris, 1990). Unfortunately, a case of cholera in a tourist in New Orleans has the same potential negative economic impact as a foreign tourist murdered while visiting Disneyworld.

The blue crab, *Callinectes sapidus*, is endemic to the northern Gulf of Mexico where Louisiana's six million acres of estuarine habitat are a major nursery ground. Reproduction occurs along the coastal shoreline and the young crabs are moved by water currents throughout the estuary. Juvenile and adult crabs complete their life cycle along the coast and within the estuarine area. They remain in the estuary throughout the winter months when they burrow into the soft organic-laden floor of the marsh. Sexually mature crabs migrate to the coastal shoreline and barrier-islands from July to November for breeding, afterwhich they die. The peak spawning period is from September to November.

Blue crabs are harvested when the carapace width is minimally some 11-12 cms; "Jumbos" may be 23 cms wide. Commercial and recreational catches will occur along the coastline but the majority of the catch is from the inland estuarine area. They can be trapped from March through November with a peak in the April and May "Spring Run". Additionally, a significant harvest takes place throughout the summer when water temperatures exceed 30°C in some places. There is also a minor peak in September, the "Fall Run". Trivial numbers of crabs are captured from November to January.

The annual economic landing value of blue crab varies, ranging from $20 million to $50 million; in 1992 they had a landing value of $27 millions and in 1993 $24 million. The total 1993 retail value generated by the crab industry was $132 million. There are approximately 1,900 commercial crab fishermen in Louisiana whose livelihood is dependent on a reliable healthy resource and a vibrant market. Over 80% of the commercial operations are family operated and situated, on average, less than 20 miles from the trapping sites. They themselves deliver about 75% of the commercial catch to market, very largely made up of seafood wholesalers and restaurants. This involves a travelling distance averaging some 25 miles. About half are also commercially involved in shrimping, a quarter are oystermen, and a few are also commercial crawfishermen. The commercial aspects of the industry are clearly an important part of the epidemiology of human cholera.

In recent years upstream residential pollution has become a large problem to crabbers especially in Barataria and Lafitte directly south of New Orleans in Jefferson Parish and in the north shore of Lake Ponchartrain directly south of Slidell. According to these persons there has been a concurrent reduction in crab offtake from these areas. When there are heavy rains, urban pollution is carried through surface run-off by storm drains which dump directly into tributaries which flow into their communities. Similarly rains can cause sewage facilities to overflow into these same tributaries. Part of the reduction in catch is due to an increase in aquatic vegetation. It must be pointed out that the Louisiana coast is sinking at the rate of 1 cm/year due to a plate shift exacerbated by the limited deposition of sediments with the result that coastal marshes and oyster beds are moving slowly northwards and thus closer to residential and industrial areas.

Gulf oysters prefer a salinity range of 10 - 30 ppt but survival of set oysters is poor above 15 ppt because of fouling and predators; oyster drills cannot tolerate salinities below 10 ppt. Setting intensity in Louisiana oysterbeds is consistently high in the salinity range of 16-22 ppt. Below 3 ppt no feeding occurs and oyster mortality increases. Separate from human epidemiological factors, such as hygiene and cooking temperatures, the *V.cholerae* available to Louisiana oysters appear to be in small numbers in highly monitored waters. Crabs on the other hand live in a wide range of salinities, feeding in a variety of depths (and thus potentially higher temperatures), nutrient levels and aquatic biota, and *V.cholerae 01* produces a chitinase allowing it to attach to the crab's exoskeleton. However, *Vibrio* spp, including *V.cholerae* and *V.vulnificus*, can be readily recovered from the crab intestine and haemolymph (Davis & Sizemore, 1982). Overall, this facilitates human infection when undercooked crabs are manually dismembered for eating. The aquatic ecology of *V.cholerae 01* is not fully understood but it benefits from the presence of a filamentous green algae, *Rhizoclonium fontanum*, for survival and maintenance of toxigenicity, and which can apparently aid it in toxin production. (Islam, Drasar & Sizemore, 1989; Islam, 1990a & 1990b) *V.cholerae* levels are in some manner positively related to the biomass of aquatic plants (Ventura, Roberts & Gilman, 1992).

Conditions for the survival and growth of *V.cholerae* occur in many estuarine environments, e.g., swamps, marshes, and nearby coastal waters. An endemic reservoir of free-living organisms exists along the Gulf of Mexico, in eastern Australia (Bourke et al, 1986), Sardinia (Salmaso et al, 1980), and probably in other similar ecological areas such as in Bangladesh (Glass et al, 1982). It can survive for long periods in warm water with a salinity of 2.5 ppt to 30 ppt and a pH of around 8.0; with added nutrients there is rapid growth (Miller, Feacham & Drasar, 1985). The environmental relationship between non-01 and 01 toxigenic and non-toxigenic strains has been reviewed (Feacham, Miller & Drasar, 1981). It is clear that these populations overlap genetically and coexist in the environment. Thus a number of environmental studies have quantitatively monitored non-01 strains in estuaries at various salinities and temperatures. For example, a study in two Florida estuaries found a strong linear relationship between *V.cholerae* recoveries and water salinity and temperature; this has been confirmed by laboratory studies (Hood et al, 1983). However, salinity is less of a controlling factor when organic nutrient levels are above 1.0 mg/l (Colwell & Spira, 1992).

A second vibrio, *V.vulnificus* , a common inhabitant of oysterbays, has recently been the cause of much public attention though it poses a negligible risk to the normal healthy population; if exposed, their attack rate is no more than 1:10,000. However, it is a significant danger to those with incompetent immune systems (e.g, HIV+ individuals, diabetics, transplant recipients) and those with liver dysfunction resulting in increased iron levels in serum. Since 1977 there have been 140 recorded human infections in Louisiana with cases from April to September. While only 32% of these affected persons are known to have consumed raw oysters, 49% of these affected oyster consumers died: the case fatality rate (CFL) was 19% for the non-consumers. Lethality really depends on the form of the clinical disease, not oysters *per se*; the CFL for wound infections was 8%, gastrointestinal symptoms 0%, and 60% CFL following primary septicaemia.

The *Vibrio* spp occupy a range of salinities with *V.cholerae* being the least halophilic, maximally <5 ppt and with negligible counts >14 ppt, but preferring water temperatures in the range 21-28°C (Seidler & Evans, 1984); *V.vulnificus* prefers more saline waters, 5-25 ppt but especially 12-15 ppt (Kelly, 1982; Kaspar & Tamplin, 1993); *V.parahaemolyticus* prefers even more saline waters and *V.alginolyticus* the open sea. There is slight growth of *V.vulnificus* at 13°C but with oysterbay waters at 17°C some 70% of oysters will be contaminated and 100% at 20° though it may be sparse in the water (A. DePaola, personal communication, 1992); above 22°C there is markedly reduced survival. Mark Tamplin, Univ. Florida, Gainesville, has derived a formula, based on his laboratory studies and field collections on the Atlantic, Pacific, and Gulf of Mexico shores of the USA that predicts *V.vulnificus* levels in water using salinity and temperature (M. Tamplin, personal communication; Tamplin, 1994). Similar mathematical models have been published for *V.cholerae* but are not as robust (Colwell & Spira 1992).

A preliminary analysis by Kenneth Hemphill, Administrator, Oyster Water Monitoring Program, of five years (1986-1990) of water quality data from the Terrebonne, Barataria and Pontchartrain oyster basins has revealed the general pattern of water movement and pollution in these basins (Hemphill, 1991). There is a surge in faecal (*E.coli*) pollution during October to April throughout all three basins, with Lake Pontchartrain having higher pollution frequencies (ie > 43 mpn/ml) than the other two and over longer periods. The general pattern is as shown in Table 1.

Table 1. Percentages of oysterbay water samples with high *E.coli* counts.

Month	Av.%Samples >43 mpn	Month	Av.%Samples >43 mpn
January	30.1	July	10.4
February	26.0	August	12.1
March	24.1	September	12.1
April	18.5	October	15.6
May	13.2	November	23.2
June	11.1	December	26.3

A comparison of high *E.coli* counts with tide status showed that falling-tides had a clear majority of their high counts in the fall-winter months, while the rising-tides' high counts tended to be in the summer. But the latter pattern varied with each basin and was inconstant. Within the Louisiana estuary, wind can and does override tidal effects, as well as exaggerate them. Winds can act as a giant pump either by southern winds forcing water into the estuaries or by northerly winds forcing water out of the upper estuary areas into the lower. They can also act as a blocking force to hold upper area drainage waters in the estuary or slow the outward movement of the upper estuarine waters. Approaching cold fronts, low-pressure systems characteristic of the relatively cooler October-March period, from the west are commonly accompanied by rainfall in the upper estuary areas. Until the front passes, countervailing winds from the southeast and south act as a blocking force to any water movement out of the estuary. As the front passes, the local winds shift to the north to move the water and rainfall washoff into the lower estuarine area, flushing the bacterial contaminates from the upper estuary into the lower basin areas. The majority of the annual Louisiana rainfall of some 60 inches is received in the hot, humid summer months when southerly winds dominate. These southerly winds will tend to block the movement of water from the upper estuary. If there is a lack of summer rain, one would expect to find saltwater intrusion into the estuaries being increased by these southerly winds.

A preliminary climatic analysis of the last 18 years has indicated the following:

[1] Widespread and numerous cases of cholera have occurred when the July-September rainfall falls to an half or a third of normal, whether measured in rain volume or raindays.
[2] "Cool" summers were as likely to have cases as "Hot" summers; i.e. it is always warm enough in summer in Louisiana.
[3] The endemic situation (i.e. few but clustered cases) is associated with short term, local shortages of rain. There would appear to be a *basin*-effect that lasts until the next heavy rain.

One can hypothesise that rain has both a mechanical flushing effect and the ability to dilute nutrients and reduce salinity.

The *V.vulnificus* modelling exercise was initiated to obtain an appreciation of the probable distribution by month within each of the oysterbays using the Tamplin formula. It was foreseen that the field sampling would be fraught with difficulties and a very high potential for wasted time unless one knew what the probable number would be before going into the field. Some of these oysterbays and associated waters take some 3-4 hours to be reached. This is also going to be the return-time of samples with associated problems of mishandling, even with experience and precautions. The Tamplin formula predicts the numbers of *V.vulnificus* organisms in oyster meat recovered from oysters in various levels of water temperature (°C) and salinity (parts per thousand).

$$\text{Log}_e \text{ organisms} = -6.32 + (0.23 \times \text{sal.}) + (0.347 \times \text{temp.}) - (0.0056 \times \text{sal.} \times \text{temp.}) - (0.0039 \times \text{sal.}^2)$$

The Oyster Water Quality Laboratory of the Louisiana Department of Health & Human Services has been examining the water in the oysterbays for over 20 years by taking water samples from specified sites. We made use of a database consisting of 118,901 records from 741 GPS defined sites from October, 1967, to July, 1993. These data include, besides record number, site and laboratory identification, the weather and water conditions, recording date, *E.coli* count (mpn/ml), salinity (ppt), turbidity, pH, tide status, water depth, and recording time for each site.

The results of this preliminary exercise will be presented. These have revealed the following, in brief:

[1] Significant but characteristic differences appear to exist in the distribution of 'risk' in the various bays. For example in Lake Calcasiu, the risk is near the coast and near-access to salt water entry; in Vermilion Bay the heavy flow of fresh water carries the risk out into the bay, essentially sea, but fortunately in an area with few oysters because of the high sediment levels in the water and oyster-reefs. This has produced individual testable hypotheses for each area in advance of the first water sampling.

[2] The importance of fresh-water flow. Where this is unrestricted, e.g., south and south-east of New Orleans thanks to the Mississippi river, the risk is markedly reduced; but where this flow is blocked the risk is much increased, e.g., in Terrebonne Parish where a ridge interrupts the water flow from the north and it is deflected to the west. Additionally, the saline water brought in by the tides and summer in-shore winds provides an ideal brackish water environment.

[3] In spite of the risks presented by certain areas, market pressures modify the reality. The 'high risk' areas in fact produce less-attractive oysters for eating raw and they are therefore used for cooking. The 'lower risk' areas, e.g., Black Bay, produce a 'pretty' oyster, highly prized by the Oyster Bars in New Orleans. These latter, extensive areas involve more fisherman than the limited high risk areas. Thus, between exposure by high-risk metropolitan individuals (e.g., with diabetes or hepatitis) eating raw oysters and the occupationally exposed fisherman and oyster handlers more cases of *V.vulnificus* arise from oysters harvested from seemingly low risk zones.

[4] Careful study of the water quality data has demonstrated that there are plenty of suitable sites for taking water samples aimed at *V.cholerae* recovery close to New Orleans. Previous plans with less knowledge had indicated that such sites would involve prolonged travel.

[5] Finally, we have a much improved appreciation of Tamplin's formula in relation to the realities of the environment, the complexities of water flows, rainfall, and tides, and thus of the laboratory-based experiments. For example, firstly the organism numbers responding to decreasing salinity following rainfall, either locally or up-stream, will track differently across the temperature 'slope' than in periods of no-rain, slower water flows, rising water temperatures, and tidal salinity pressures; secondly, for laboratory studies characterising organism numbers in relation to temperature, salinity, sediment, and organic levels of Louisiana waters. It should be remembered that the Tamplin formula was derived from 27 sites in 14 different states.

All in all it is a complex environment and answers will not be easily or rapidly obtained. There are a number of factors in our favour however. Firstly, seafood and mariculture is a major and important agricultural industry in the state, both economically and socially. Secondly, there is a rich width and depth of local scientific expertise to be drawn upon, from inside the university, the State Department of Agriculture, and of Public Health. Lastly, with modern satellites we can measure the water temperatures with high accuracy throughout southern Louisiana at any frequency day and night; the university has its own downlink on campus. We have yet to develop or access an equally cheap and rapid method of measuring water salinity throughout these areas. This might have to be done by modelling.

ACKNOWLEDGEMENTS

The generous help and advice of Andy DePaola and Mark Tamplin is gratefully acknowledged.

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REQUIREMENTS OF A GEOGRAPHICAL INFORMATION SYSTEM TO BE USED DURING A FOOT-AND-MOUTH DISEASE OUTBREAK

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A prototype decision support system (DSS) for the control of foot-and-mouth disease (FMD) is under development within the EpiMAN(EU) project (Donaldson 1993,94,95). The DSS consists of a central database for farm information, a geographical information system (GIS) for spatial data, epidemiological and economic simulation models, and expert systems containing factual knowledge about FMD. The DSS was originally designed in New Zealand (Sanson, 1993). The aim of the DSS is to support the decision makers in both the operational and tactical management during an outbreak of FMD, but the system may also be used as a training tool for all people involved (Jalvingh et al., 1995). In this paper, the GIS application of EpiMAN (EU) will be discussed.

Potential GIS tasks

When an outbreak of FMD occurs in the European Union (EU), the afflicted country has to control the disease as quickly as possible, and has to follow EU requirements for the control procedures as described in Directive 85/511/EEC (Anonymous, 1985). Certain control tasks require spatial information and may be facilitated by using a GIS (Mackay, 1994).

The definition of restricted areas around an infected premise (IP) is an example of a spatially oriented task. According to EU regulations, two restricted areas are minimally required. The smallest area, the protection zone, has a minimum radius of 3 km around the IP, and the next area, the surveillance zone, has a minimum radius of 10 km. In both zones the livestock holdings and related industry are put under severe restrictions, which will only be lifted after extensive clinical, serological and epidemiological research has proved that the outbreak is finished. A list containing all farms, with animal numbers, within the zones is therefore needed. To facilitate enforcement of the control measures in the zones and to prevent movements of animals to and from the zones, the borders should follow geographical boundaries, such as motorways, waterways, or railroads (van der Meijs, 1993).

Another task which requires spatial information is the identification of farms that may have been covered by a virus plume from the IP. Several simulation models exist, which can

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simulate the spread of FMD virus that has been exhaled into the air by infected animals on the IP (Gloster et al., 1981, Donaldson 1994 & 1995, Maragon et al., 1994, Moutou & Durand, 1994). Given the location of the IP and the weather conditions such as wind speed, wind direction, relative humidity, precipitation, and cloud cover, farms that are covered by the simulated virus plume can be identified.

EpiMAN(EU) GIS application

The GIS of EpiMAN(EU) is programmed in Arc/Info and runs on a Unix machine. The user is provided with menu-driven interfaces, and does not need to know Arc/Info to carry out the GIS tasks. The database for the GIS is not kept on Info, but on Oracle, a relational database. This database is also available to the users through Access, a PC-based relational database. The users of EpiMAN(EU), with the exception of the GIS tasks, will therefore only work on PC's, which are connected to the Unix machine.

To define restricted areas, a menu is available in EpiMAN(EU). The user can easily draw the borders with the mouse on screen, following the geographic features as visible on the maps. Once the zones are decided and stored on the database, a list of farms within the zones can be generated automatically (Donaldson, 1995).

For the prediction of the virus plume, another menu is available in EpiMAN(EU). Within this menu, a virus production module is available, which automatically calculates the virus source strength, based on the age of the lesions and the number of infected animals on the IP (Donaldson, 1995). For those days with a sufficient virus production, weather data should be available. The weather data can be entered into EpiMAN(EU) semi automatically. If both weather recording data and virus production data are available, a virus plume can be calculated. The model for the calculation of the plume is a combination of a flow model (LINCOM) and an atmospheric dispersion model (RIMPUFF), and was adapted for EpiMAN(EU) in cooperation with the developers (Mikkelsen & Thykier-Nielsen, 1993ab, Donaldson, 1995).

EpiMAN(EU) data requirements

To use the GIS functionality of EpiMAN(EU), digitized spatial information is needed. Ideally, digitized maps of a sufficient precise scale should be available, as well as the exact locations of all farms. However, most EU countries do not have this information readily available at the moment, so information needs to be gathered or updated during an outbreak. The EpiMAN(EU) software was developed to be flexible with regard to the availability and quality of digitized data.

The goal of the current study was to test the GIS functionality of the EpiMAN(EU) software, and to define the quality and (non)availability of data in the Netherlands.

MATERIALS AND METHODS

To test EpiMAN(EU), data were collected in a geographically defined area of approximately 33 km^2 in the eastern part of the Netherlands (Nielen et al., 1995, Nielen et al., 1996). Farm records of the farms in the study area were provided by the Animal Health

Service in the Netherlands, which keeps updated records of all commercial farming enterprises. Farm records are identified by a unique 7-digit number (UBN) and include owner's name, full address, type of animals, and type of establishment, among others.

In addition, data such as farm locations had to be collected for the GIS database. In Epiman(EU), a farm location is defined as a point location and consists of an x,y coordinate pair, both in meters. The x,y coordinate should locate the farm buildings. This is in contrast to the system as it was developed in New Zealand, where farms were defined by the land parcels that belonged to a farmer (Sanson, 1993). For the Netherlands, relative x,y coordinate lines are routinely available on the maps as provided by the Dutch Topographical Service (TDN). However, digitized information on the farm locations was not available at the start of the project.

For the study, all participating farms in the selected area were visited to collect data. During the farm visit, the location of the farm building(s) was recorded on a copy of a 1:10,000 black-and-white paper map, as available from the TDN. The 1:10,000 maps are mainly based on satellite photographs, and show all the buildings, to the detail of each separate structure. In the Netherlands, digitized maps are commercially available. The TDN offers vector maps of scale 1:10,000, but also raster (scanned) maps of scale 1:25,000. The coverage of the buildings of this map is the same as on the 1:10,000 maps. In the EpiMAN(EU) GIS application, 2 coloured raster maps of scale 1:25,000 that covered the study area were initially used as backdrops. At a later stage, 1:10,000 vector maps of the area should become available. Using the EpiMAN(EU) software, the farm locations were transferred from the paper maps to the GIS database. To do this, the mouse was placed on the farm buildings, clearly visible on the scanned 1:25,000 map, and the UBN was typed into a menu screen. The combination of UBN and resulting x,y coordinates was automatically combined with the other farm data, that had been transferred to the Oracle tables.

A potential source of approximate farm locations has become available through the Dutch Cadastre, which is in the process of digitizing its information. Currently, approximately 60% of Dutch addresses, based on a 6 digit postal code and house number, are georeferenced. The resulting x,y coordinate is the centroid of the land parcel that is connected to the postal address. As a test, the x,y coordinates of the farms according to the cadastre were compared to the manually digitized coordinates.

To test the GIS functionality of the restricted zones and the virus plume menus, a pig farm in the centre of the area was declared infected. Virus production was based on 10 pigs with 1 day old lesions at the day of clinical diagnosis. Weather recording data were available for a period of 14 days, with hourly data of the relevant parameters.

RESULTS AND DISCUSSION

Farm locations

The GIS application made it easy to digitize the farm locations on screen. During an outbreak, missing farms can be easily added by this method and wrongly located farms can be easily moved with the same user interface. However, digitizing on screen does not seem to be a feasible option to georeference all farms in the Netherlands.

The cadastre data seem a better option to quickly collect an approximate farm location, if the quality is adequate for the goal of disease control. Quality was defined as percentage coverage and distance from hand digitized farm locations. In total 155 hand digitized farm locations were available, with 119 corresponding cadastre data, a coverage of 77%. The results of the comparison for the study area are in Table 1. Approximately 50% of the cadastre data were within 53 meters from the hand digitized location, and 80% were within 110 meters. A few outliers occurred, 3 observations were widely off, between 1 and 3 km, possibly caused by a wrong address (owner does not live on farm).

Table 1. Distance (in meters) between hand digitized x,y location of farm buildings, and x,y coordinates according to the Dutch Cadastre (N = 119).

Mean	134
Median	53
Minimum	7
Maximum	3353
95% CI for Mean	60 - 208

Even if the cadastre data were not perfect, they seem to be the easiest way to achieve a quick approximate location of farms in the Netherlands. In the case of an outbreak, the farm locations in the outbreak area will have to be edited, and missing farms will need to be added, both of which are possible with the EpiMAN(EU) software.

Restricted area menu

The protection and surveillance zones could easily be drawn with the mouse on the screen. The facility for drawing an automatic circular zone with a user defined radius was very helpful to start with a correct minimum size of the area. The user can then adapt the border of this circle according to geographical boundaries. The user can zoom in and out during the drawing of the border, depending on the detail that is needed. For example, in an area with many farms close together on both sides of a road, it is very important that the border is exactly on the road. In those instances the user can zoom in during the drawing process. Before a final zone is decided upon, the user can ask for farm information on all farms, but in particular farms close to the borders would be of interest. Depending on farm characteristics, such as size or animal species, the border of a zone could be changed to include or exclude some farms. In addition, the user might want to extend the zone in the direction of the simulated virus plume, to include potential at-risk farms. All in all, a non Arc/Info adept could easily handle the GIS tasks related to the definition of the restricted areas.

The list of farms within the restricted areas may of course be incomplete. If farms are not georeferenced, x,y coordinates are not available in the database. Even if the true farm location was within the restricted area, the farm would not show up on the GIS based, automatically generated list. However, a list of farms without x,y coordinates is also provided, so a person with local knowledge could localise such farms on the map and add their location to the database. Using the Access interface, queries on postal code could also be performed, if certain postal codes are completely included in the restricted area. A map of the postal code areas is commercially available in digitized form in the Netherlands.

Virus plume menu

The virus plume menu provides the user with information on the existence of a virus source and the availability of weather data on the days with virus production. The user can decide for which days the model should run. The virus plume model calculates the accumulated virus concentration per m^3 over 24 hours, and a plume should be calculated for each day of virus production. The user can define the size of the grid that is used in the calculation, and can start with a large grid, for example 500 x 500 metre, to get a first general idea of plume size and direction on a certain day. If a sizable plume occurs, the user can recalculate the plume with a finer grid, so that the virus concentration boundaries become smoother. The plumes need to be saved per day. Once a plume is saved, a list of farms under the plume can be generated automatically. The user might want to adapt the protection or surveillance zone to include farms that could have been under a virus plume. Therefore the plumes can be shown on the screen for all menus and are automatically resized with the zoom factor.

During the development of EpiMAN(EU), it became clear that the plume model should only be used if a person with meteorological knowledge is available to assist the veterinary epidemiologists. Many assumptions in the model are meteorologically based and have a large influence on the interpretation of the simulated plume. The quality and frequency of the weather data has to be taken into account, as well as the validity of weather data from the (mostly) nearest airport for the area around the IP. The colourful drawings of impressive plumes might otherwise generate unwarranted panic and improper decisions on the size of a restricted area.

Dutch data availability

Availability of data for the Netherlands is not extremely bad. Digitized maps of the total country are available, although expensive. Unfortunately, we did not receive the 1:10,000 vector map in time to compare it with the 1:25,000 scanned map. However, the 1:25,000 scanned maps had sufficient detail to perform all the GIS tasks. The x,y coordinates based on the Dutch Cadastre information might be used initially for an approximate localization of the majority of the farms. The Animal Health Service is expected to add this information to its database in the near future. Digitized farm information is already available from the Animal Health Service. Precise animal numbers are available for cattle through the National Identification & Registration system. This system consists of a central database in which every cow in the Netherlands is identified by a unique 9 digit cow number, which is combined with the UBN of the farm where the cow is located. Farmers are obliged to report each cow movement to the central computer within 3 working days. They can do so by voice response system (telephone), by modem, or through local cattle improvement associations. For pigs, approximate data on animal numbers are available, because all commercial farms are sampled at least 3 times each year for Swine Vesicular Disease, and all animals on the farm are counted at such sampling. This information is recorded by the Animal Health Service. For sheep and goats no central data on animal numbers are available yet, so these, and other susceptible species, will have to be counted in the restricted areas during an FMD outbreak.

CONCLUSION

The EpiMAN(EU) GIS application was user friendly and provided the user with good tools to facilitate certain tasks in the control of a FMD outbreak. The system could be used in the Netherlands, and has potential for other countries as well. However, digitized data have to be available in advance of an outbreak, which is not completely the case yet in the Netherlands. To fully utilise the possibilities of a DSS such as EpiMAN(EU), a permanent, updated database with full farm information, including farm locations, is necessary.

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CLAW DISORDERS AMONG DAIRY COWS IN ORGANIC AND IN DEEP BEDDED PACK BARN SYSTEMS IN DENMARK

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Lameness has been recognised as a major health disorder in dairy production and a welfare problem causing pain and long term effects on physiology and behaviour. Most incidents of lameness are related to the claws. Claw disorders are currently regarded as typical examples of multifactorial production diseases.

Recently, deep bedded pack barn and organic dairy production systems have gained popularity in Denmark. The organic dairy systems are characterised by the following legislation rules: 1) 85 % of feed ration must be of organic origin. In practice this means a fibre rich ration compared to typical conventional feeding regimes, 2) daily exercise for all animals, 3) grazing at least 150 days during the summer, 4) straw bedding for all animals, 5) preventive medication prohibited, and 6) prolonged withdrawal time (compared to conventional farming systems) for milk and meat after treatment with veterinary drugs. These rules, especially rules number one to four, are expected to influence claw health.

The deep bedded pack barn and the organic dairy cow systems have been in operation for a limited time only. The epidemiology of claw disorders in these systems has not been described in much detail yet.

The objectives of this paper are: 1) to describe the results of a study of claw health in a broad spectrum of deep bedded pack barn and organic dairy cow production systems, including an identification of risk factors related to claw disorders in these systems, and 2) to discuss difficulties in the epidemiological analyses of the data set, suggesting alternative ways of analysing data like this in future scientific studies of claw health.

MATERIALS AND METHODS

The herds

Seven conventional and six organic herds were included in the study. All cows were dual purpose breeds. In eight of the herds the cows were Danish Friesian Dairy Cattle (SDM). Herd size was from 42 to 94 cows per year. The housing systems were tie stall systems (three conventional and three organic herds), deep bedded pack systems (four conventional and two organic herds), and one free stall housing system with slatted floor (organic).

Recordings

Recordings were performed during the period November 1991 to May 1993. Each herd was represented by up to four claw trimmings where all lactating cows were trimmed. Recording of claw health was performed by the claw trimmer (the same in 10 herds). He performed 1545 trimmings in total with an electrical claw trimmer. Three claw trimmers performed the remaining trimmings. All claw trimmers were trained in using the recording form (optional recording in the national health recording system).

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Body weight was obtained by project technicians every six months. Information about cow characteristics (e.g. parity, milk yield, and calving dates) was obtained from the Danish National Health Recording System. Data were verified by comparing different sources of information.

Data editing

After correction for coding errors, 1842 observations on 974 cows had a full set of records. A four level nominal response variable, afterwards called "claw disorder", was defined as follows:
1) Acute haemorrhage, which includes diffuse red colouring of the sole, red/white line and remarks about haemorrhage in the distal part of the sole ("toe").
2) Only one leg affected with slight or severe sole ulcer localised to a distinct area of the sole, with or without remarks about double sole, double wall or loose claw capsule.
3). Two or more legs affected with slight or severe sole ulcer localised to a distinct area of the sole, with or without remarks about double sole, double wall or loose claw capsule.
4) No remarks.

Explanatory variables defined in Appendix 1 were created for the analyses at cow level. The herds were divided into 7 herd groups according to production system (organic or conventional), housing system (deep bedded pack barn, tie stall or slatted floor) and breed (SDM or not SDM), as presented in Appendix 1.

Statistical Analyses

The four level response variable "claw disorders" (defined in the section Data Editing) was analysed in a multinominal logistic regression analysis.

A multiple correspondence analysis (Proc Corresp in SAS) based on the variables listed in Appendix 1 was carried out initially. Based on the results of this analysis, interaction terms were selected for the initial regression model. Sixteen two-factor interaction terms were included in the initial model. The strategy for examining interaction terms in this model was a backward elimination strategy (e.g. described in Enevoldsen & Sørensen, 1992). Because the final model was very complex and difficult to interpret, four smaller data sets were formed:
1) First parity and early lactation (calving to 120 days post partum), N=250,
2) First parity and late lactation (from 120 days post partum and onwards), N=440,
3) Second parity and later, and early lactation (calving to 120 days post partum), N=455.
4) Second parity and later, and late lactation (from 120 days post partum and onwards), N= 697.
These four data sets were analysed following the same guidelines as the main analysis (excluding parity and lactation stage as possible risk factors).

RESULTS

Table 1 shows the prevalence of claw disorders included in the response variable, observed at claw trimming. Furthermore, the table presents bivariate associations among claw disorders and a number of variables which were found to be significantly related to claw disorders in the analyses of the sub-data set. A more comprehensive presentation of uni- and bivariate associations among explanatory variables and the response variable is given in Vaarst et al. (1996).

Ten interaction terms could not be eliminated from the initial model at the applied modelling strategy. Thus the final model was very complicated. Table 2 presents the p-values of each interaction term where it is excluded from the final model and where it is compared to this model and to the initial model. Herd group interacted significantly with a number of risk factors. Parity and lactation stage interacted strongly and interacted furthermore with other risk factors. Herd type, parity, and lactation stage appeared to be the key

Table 1. Bivariate associations among cow level risk factors and laminitic disorders observed at 1842 claw trimmings, performed in 7 conventional and 6 organic herds with dual purpose cows. (DB= Deep bedded pack barn systems. LH= Loose housed. TS= Tie stall. SDM= Danish Friesian Dairy Cow.
OD= Other dual purpose breeds).

	% without disorders (n=1356)	% with acute haemorrhage (n=119)	Sole ulcer, %		Total N (%) (n=1842)
			One leg only (n= 97)	Two legs or more (n= 270)	
Calving Season, %					
Early grazing	31	38	34	37	604 (33)
Late grazing	27	28	28	24	485 (26)
Early housing	15	20	18	20	299 (16)
Late housing	27	14	21	19	454 (25)
Disease treatments, %					
None	66	57	55	54	1157 (63)
Udder disorders	25	28	28	32	491 (27)
Repro. disorders	2	8	2	3	46 (2)
Other	7	7	15	11	148 (8)
Herd groups, %					
DB, SDM, conv.	19	15	10	26	359 (19)
DB, ODPB, org.	11	16	14	11	208 (11)
DB, ODPB, conv.	17	3	17	10	271 (15)
LH, SDM, org.	16	37	25	27	358 (19)
TS, ODPB, org.	9	0	2	3	125 (7)
TS, SDM, org.	12	18	18	11	224 (12)
TS, SDM, conv.	17	12	14	13	297 (16)
Heel horn erosion, %					
Present	12	6	8	12	216 (12)
Not present	88	94	92	88	1626 (88)
No. of trimmings during study period, %					
First	50	66	64	60	974 (53)
Second	31	25	19	24	540 (30)
Third or more	19	9	17	16	328 (17)

Table 2. Interaction terms which could not be eliminated from the initial model. The importance of each interaction term is indicated through: 1) p-value when included into a model of main effects as the only interaction term, 2) when excluded from the final model and compared to the final model, and 3) when excluded from the final model and compared to the initial model[1]. All values based on Analysis of Deviance.

Interaction terms:	Included in main effect model	Excluded from final model[1] Compared to:	
		Final model	Main Model II
Herd Group			
Previous Milk Yield	0.239	0.027	0.002
Body weight	0.314	0.017	0.001
Parity	0.060	0.011	0.001
Lactation Stage	0.172	0.040	0.002
Calving season	0.142	0.070	0.003
Parity			
Lactation Stage	0.004	0.000	0.000
Disease Treatment	0.000	0.007	0.001
Lactation stage			
Disease Treatment	0.326	0.004	0.000
Calving Season	0.124	0.012	0.001
Disease treatment			
Body weight	0.288	0.116	0.005

[1] Initial model -> final model: Analysis of Deviance, p-value= 0.0103

factors in the model. Consequently, sub-data sets were formed based on parity and lactation stage, as described in 'data editing'.

Tests indicating a good fit for binomial logistic regression (likelihood ratio, residual plots, normal distribution of residuals), suggested an acceptable fit, but must be interpreted with caution. Diagnostic tests specifically designed for multinominal logistic regression models are generally difficult to perform and interpret (Hosmer & Lemeshow, 1989) and were, consequently, not carried out.

Three of the four models based on the sub-datasets were relatively uncomplicated. The model of the dataset based on older cows in late lactation was, however, very complex due to numerous interaction terms.

Herd group was a significant risk factor in all three analyses. The presence of heel horn erosion was significantly related to claw disorders among cows in first parity, early lactation. Trimming number was a significant risk factor related to claw disorders in first parity cows in late lactation. Calving season, disease treatment and number of claw trimmings were significantly related to claw disorders in cows from second lactation and later, in early lactation. The presence of reproduction diseases was positively related to acute haemorrhage and negatively to sole ulcer. First claw trimming appeared to be a significant risk factor in this group of cows also. The estimates also suggested a rank among levels within each risk factor, irrespective of the reference level. In this analysis, the ranking of levels within the variable 'herd group' was interesting. Predictions from the three uncomplicated models showed that the risk for one of the claw disorders (e.g.. 'acute haemorrhage') could be different for different groups of cows within the same herd group. Similarly, within a given group of cows (e.g. 'cows in parity one, early lactation') from the same herd group, the risk of having sole ulcer in one leg could be low, whereas the risk of having sole ulcer in two or more legs could be high.

DISCUSSION

The multinomial logistic regression analysis revealed a very complex pattern of interrelations between the response variable 'claw disorders' and a number of risk factors. The structure of the final model was thus difficult to interpret. Consequently, the conclusions of the analysis with regard to associations between claw disorders and a number of risk factors were relatively vague. However, the interrelations between explanatory variables were very important for obtaining a valid model.

The statistical analysis was based on associations between a response variable formed from prevalence examinations of claw disorders and time dependent explanatory variables. The importance of evaluating time aspects in the data set more efficiently was underlined.

This complexity of the model could be due to a correct description of the data. It could also be an artefact due to data problems or modeling strategy. These questions are discussed in the following together with suggestions for alternative analyses.

Data quality

Recordings of claw health were performed by the same claw trimmer in 10 herds (1545 trimmings) and all 4 claw trimmers involved in the study were trained in using the recording form as a part of the national health recording system. Claw trimming recordings should, consequently, be regarded as reliable data. Other information obtained for the analyses was verified by cross checking performed by project technicians and project veterinarians and was, consequently, also regarded as reliable data.

Claw health in deep bedded pack barn and organic cow production systems

The associations between variables found in the multinominal cow level analysis of all data did not reveal one unambiguous structure in the data. However, despite the complexity of the final model some associations or tendencies were revealed. These were generally consistent with findings in other studies. A discussion regarding the biological plausibility of relations between each risk factor and the response variable is presented in Vaarst et al. (1996).

The statistical and epidemiological analyses

The herd group variable: The variable 'herd' is expected to represent herd specific management routines which were not quantified in this study. In this study, herd groups were based on breed, production system, and housing system. These three risk factors were expected to influence claw health significantly and furthermore, they were expected to be strongly interrelated. Grouping herds brings along a more manageable and easily interpretable description of their influence on the response variable.

The criteria for grouping herds seemed logical. From numerous studies, breed (especially cows of the Friesian type) and housing system have been shown to influence claw health. The feed ration in organic farming systems is characterised by a higher roughage:concentrate ratio compared to conventional herds, as discussed in Kristensen et al. (1994)). Management routines with regard to feeding strategies were thus partly taken into account in the analyses through grouping by production system.

The associations between herd group and claw disorders were very difficult to describe and interpret. The presence of herd specific management routines and conditions others than the ones taken into account when grouping herds could explain some of the complexity in the final model. However, reliable data characterising herd specific management routines are very difficult to obtain in practice. If single well-defined management routines (e.g. feeding strategies after calving) or conditions (e.g. surface of the exercise areas) were included in a study such as this, the number of combinations of different strategies would most likely be equitable to the number of herds. Herd specific management routines would most likely influence claw health, but data describing these routines and conditions were regarded as very difficult to obtain and include as risk factors in a study like the one carried out.

If reliable data describing herd specific management strategies could be obtained, it would be possible to describe claw health within farm through a case study approach, which would be a relevant alternative in order to reduce this complexity (Meek, 1991). In case studies it may be possible to make a more qualitative assessment of the herd specific claw disorder patterns as well as herd specific risk factors.

Another alternative would be to include the variable 'herd' representing the herd specific management routines as a fixed or random effect in the model. Because the objectives of the study were to describe the magnitude and direction of each herd's or herd group's influence on claw health, the chosen strategy was regarded as the most appropriate.

Associations among explanatory variables: Explanatory variables were categorised into 2 to 4 levels each (except for herd group). The categories seemed to be of biological relevance. It was practically impossible to perform a multinomial logistic regression analysis including all possible two-factor interaction terms. The choice of interaction terms included in the initial model were mainly based on the results of a corresponding analysis carried out initially in conjunction with a subjective evaluation of each risk factor. However, the presence of several significant interaction terms showed a very complicated data set with variables that seemed to influence each other with regard to associations to the response variable. This made the interpretation of the final model practically impossible.

In order to understand and describe the entire pattern of associations among risk factors possibly related to claw disorders, it might be beneficial to evaluate the dynamic pattern (time aspects) among variables in more detail. Phenomena like confounding and intervening variables might prove more accurate explanations of some of the interrelations found between variables.

Another possibility - which must also be preceded by an evaluation of possible time dependent and causal relations among variables - would be to examine the dataset in a so-called graphical model. The Danish semi-automatic block recursive model "Bifrost" (Vaarst et al., 1994; Hojsgaard & Thiesson, 1995), could offer promising opportunities to come to a closer understanding of the complex pattern of interacting factors suggested from these analyses.

Prevalence examinations and time aspects: The response variable of interest was based on claw trimming data collected at prevalence examinations. Some claw disorders must be expected to be of chronic and partly subclinical character. The onset of a given case of the claw disorder was not known when observing the condition at claw trimming. Other claw disorders were regarded as being of highly acute character. 'Acute haemorrhage' was regarded as an acute condition. The response variable was divided into four levels to account for the time aspect of claw disorders.

However, the complexity of the analyses indicated that the response variable still was not formed in a way that could describe the associations between claw disorders and the time related explanatory variables in an appropriate and unambiguous way. Further division into more levels would, however, not be realistic in order to analyse a data set like this. A binary response (e.g. 'claw disorders yes/no') would not reflect the time aspects within the response variable and was, consequently, not regarded as relevant.

As mentioned above, all variables were categorised in an attempt to take the time aspect into account. The time aspects of some of the variables (shown in Appendix 1) were not completely precise. E.g. the variable 'grazing season' was placed from June to December. The grazing period started during the first weeks of May in most herds. On 1st June all cows were grazing. Similarly, the housing period started in some herds in the beginning of November, and in some herds the cows were still grazing during the day time until late November, and housed during the night. The 'effect' of being housed would most likely become obvious within weeks after the environmental change had taken place, and definitely not before. However, in case a cow was housed early November and experienced an acute haemorrhage shortly afterwards, this might have been neglected in the analysis because the housing period was defined from 1st of December in the variable. Experimental reclassification of some of the time dependent explanatory variables would appear to be the most relevant solution such cases.

It is questionable whether it would be possible to describe the dynamic development of the associations between a disease complex like laminitis and explanatory variables with sufficient precision using traditional statistical models such as the one applied in this study. A case study approach as suggested above might be a relevant alternative in order to account for the development over time and possible feed-back mechanisms (Meek, 1991).

Multinomial logistic regression: In this study, a backward elimination strategy was used. Sixteen interaction terms were included in the initial model. As mentioned before, selection of interaction terms was based on multiple correspondence analysis and subjective evaluation of each risk factor included. E.g. the variable "number of claw trimmings" was included to account for repeated measurements and was not included in any interaction terms. The majority of the included interaction terms were considered to be of biological relevance.

A model fitted through a forward inclusion strategy (Hosmer & Lemeshow, 1989) would probably be less complicated and include only a few interaction terms (as indicated by table 2) and proportionally easier to interpret. In this study, an obvious difference among herd groups was seen from the descriptive analysis alone. A complicated risk factor pattern particularly related to herd type was, consequently, not surprising. A model where these interaction terms could be taken into account was therefore regarded as most appropriate at the expense of an easier interpretation in a weaker model. The simple model also showed a highly significant lack of fit. The easily interpretable parameter estimates would, consequently, be invalid. The number of important interaction terms that was revealed may, however, lead to the conclusion that the benefit of a study of this type is limited.

In conclusion, the present study has raised several important questions related to analysis of associations among prevalence data and time dependent data and how to improve data editing and model building in a study. The need for a more careful and efficient examination and evaluation of time aspects in a given data set became evident. Alternatives for future studies are suggested. A case study approach alone or in combination with graphical models where dynamic aspects and development over time could be included seem to be attractive options for future studies.

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Appendix 1. Information about explanatory variables included in the analyses.
The herd group variable is described seperately.

Variable	Definition	Levels	n (%)
Body weight	Deviation from expected body weight calculated as average body weight for each herd adjusted for parity and lactation stage	Lower than expected (< -20 kg)	492 (27)
		Expected level (-20-+10 kg)	599 (33)
		Higher than expected (>+10 kg)	614 (33)
		No information	137 (7)
Milk yield per day	Deviation from expected milk yield adjusted for lactation stage and parity	Lower than expected (< -1.1 kg)	505 (27)
		Expected level (-1.1-+1.5 kg)	552 (30)
		Higher than expected (>1.5 kg.)	624 (34)
		No information	161 (9)
Calving season		Early grazing (June-August)	604 (33)
		Late grazing (Sep.-Nov.)	485 (26)
		Early housing (Dec.-Jan.)	299 (16)
		Late housing (Feb.-May)	454 (25)
Parity		First	690 (37)
		Second	506 (27)
		Third and later	646 (35)
Lactation stage		Calving-60 days post partum	341 (19)
		61-120 days post partum	364 (20)
		121-250 days post partum	706 (38)
		251 days post partum to calving	431 (23)
Disease treatments	Disease treatments performed by the veterinarian	None	1157 (63)
		Udder related disorders	491 (27)
		Reproduction disorders	46 (2)
		Other disorders	148 (8)
Heel horn erosion		Present	216 (12)
		Not present	1626 (88)
Number of trimmings	Number of trimmings during the study period	First	974 (53)
		Second	540 (30)
		Third or more	328 (17)

The categories of the herd group variable were formed on the basis of housing system, breed, and production system as described in the table.

Herd group	Housing system	Breed	Production system	n (%)
1	Deep bedded pack barn	SDM	Conventional	359 (19)
2	Deep bedded pack barn	Other dual purpose	Organic	208 (11)
3	Deep bedded pack barn	Other dual purpose	Conventional	271 (15)
4	Loose house, slatted floor	SDM	Organic	358 (19)
5	Tied stall	Other dual purpose	Organic	125 (7)
6	Tied stall	SDM	Organic	224 (12)
7	Tied stall	SDM	Conventional	297 (16)

VETERINARY PRACTICE AND OCCUPATIONAL HEALTH

AN EPIDEMIOLOGICAL STUDY IN SEVERAL PROFESSIONAL GROUPS OF DUTCH VETERINARIANS

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Although veterinary medicine can be a rewarding occupation, veterinarians must deal with distinctive health risk factors. Occupational hazards are common in the agricultural industry, and especially also among veterinarians (Wiggins et al., 1989). In the Netherlands, the proportion of veterinarians with a period of occupational disability of more than one year is significantly higher than in comparable occupational groups (dentist, physician), and has increased with 30% between 1985 and 1990 (Boon, 1992). Clinical and epidemiological studies have suggested that veterinarians are at risk from many occupational illnesses including site-specific cancers (Blair & Hayes, 1982), fetal loss (Moore et al., 1993), pesticide-associated toxicity (Schuchman et al., 1975), zoonotic infections (Richardus et al., 1984), contact dermatosis and respiratory tract illnesses (Falk et al., 1985; Donham et al., 1986) and trauma (Landercasper et al., 1988).

In 1990 an epidemiologic study was initiated in the southern region of the Netherlands to investigate the relationship between professional practice of swine farmers and their health status (Preller, 1995). Because most large-animal practitioners have to work under similar working conditions as swine farmers, the Animal Health Service and a pulmonary specialist of a hospital began a survey into health problems of veterinarians registered in the Southern Netherlands (Tielen et al., 1992; Tielen et al., 1996). The study indicated similar prevalence of respiratory disorders in large-animal practitioners as in swine farmers. Large-animal practitioners reported more asthmatic attacks than swine farmers. There are several studies on swine farmers showing an increased risk for respiratory disorders for this occupational group (Bongers et al., 1987; Zejda & Dosman, 1993).

Exposure to dust can have negative effects on lung function (Zejda & Dosman, 1993). Practitioners can be exposed to dust from feed, pollen, dandruff, epithelial layers, hair, faeces, and urine on the one hand and bacteria, mites, fungi and their excretion products on the other hand. Exposure to dust is especially high in swine and poultry buildings (Clark et al., 1983). Endotoxins are part of the cellular barrier of gram-negative bacteria. Animal faeces especially is an important source of gram-negative bacteria. Exposure to endotoxins can have negative effects on the lung function and is accompanied by complaints like coughing

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and shortness of breath (Rylander & Snella, 1983). Part of the dust particles comprising bacteria and fragments of bacteria are respirable and can penetrate deeply into the lungs. Up till now, there are no internationally recognized limits for exposure to endotoxins.
The results of the survey gave rise to further inquiries into occupational health and exposure to risk factors in the working environment of veterinarians. This paper will focus on possible disorders of the respiratory tract. Emphasis is laid on prevalence of allergy, lung function disorders and bronchial hyperresponsiveness. Furthermore, measurements in the occupational environment of the veterinarian (dust, endotoxin) are discussed.

MATERIAL AND METHODS

From a database with 493 veterinarians who participated in the first survey (Tielen et al., 1992), 102 veterinarians were randomly selected. Depending on the professional activities (working ≥ 50% of time predominantly with certain species), the study population consisted of five groups of approximately twenty veterinarians each working with swine, cattle, poultry, pet animals and other (non-practitioners working for the government, academia, industry, etc.). An informed consent and information on the investigation was sent to them by October 1993. Furthermore, 150 Dutch guilders were asked from the participants as partial compensation of the costs of the study. When no consent was given, the reasons were asked.

To support the anamnesis, participants were asked to fill in a questionnaire and send it to the Hospital prior to the medical examination. The questionnaire was constructed based on the example of the medical questionnaire A (basic inspection) of the National Association of Dutch Physicians. Questions on health condition, hospitalisation and accidents were asked. Furthermore, additional questions asked for possible partial or complete interruption of work due to an accident or disease in the last 12 months.

The medical examination took place in the period of November 5th 1993 till May 3rd 1994 in the Elkerliek Hospital in Deurne. First, a blood sample was taken. Next, a physical, a lung function, a X-ray-thorax examination and a skin test were executed at the out-patient clinic.

In order to establish the amount of air that one can breath in and out and to determine whether the airways have a normal passage, one can execute a lung function examination (spirometry). Strictures decrease the passage of air in the airways. Strictures can be highly temporary or temporary, e.g. during asthmatic attacks or acute incidental exposure to a substance, but strictures can also be permanent caused by a prolonged exposure to substances. Spirometry is especially suited to demonstrate or exclude obstructive and restrictive respiratory disorders. With obstructive disorders, a decrease of air flow is seen during expiration. With restrictive disorders, a decrease in air volume is seen. In this case the total lung capacity and the vital capacity show a decrease. In general this is also the case with the expiration velocity. The spirometry in our study was executed with a water filled Pulmonet 2400 spirometer with a Helium dilution (Godart, Bilthoven, The Netherlands). Preceding the lung function measurement, the participant was instructed according to guidelines of the EGKS (Quanjer, 1983). The following lung function parameters were recorded for data analysis: forced vital lung capacity (FVC in L); forced expiratory volume in the first second (FEV_1 in L); FEV_1/FVC ratio (%); forced expiratory flow between 25% and 75% of expiration (FEF_{25-75} in L/sec); forced expiratory flow at 50% of expiration (FEF_{50} in L/sec). With conversion formula the values were corrected for temperature and air pressure.

A histamine provocation test has been formulated to determine whether the airways have the tendency to constrict during inspiration of irritating, non-allergenic substances. For this, different increasing concentrations of histamine are used. The histamine provocation test was performed according to a method described by Cockcroft et al. (1977), using a PARI atomizer to produce the aerosol (Paul Ritzan, Pariwerk, Stanberg am See, Germany). The atomizer was filled with 2 mL of the test fluid and vaporized with pressed air (5 L/min). The participant inhaled the vapor for half a minute. The provocation started with inhalation of a physiological salt fluid, followed by increasing doses of histamine-chloride in doubling concentrations, starting with 0.25 mg/mL. The test was continued until FEV_1 decreased by 20% or more compared to the value obtained from the physiological salt fluid or a histamine-chloride concentration of 32 mg/mL was reached. A decrease of 20% or more in FEV_1 and/or FEF_{25-75} at a concentration of 8 mg/mL histamine was used as an indication of increased bronchial hyperresponsiveness.

Participants were injected intracutaneously a standard panel of several different allergens (0.03 mL of solution) in both shoulder-back regions. The standardized allergens (ALK, Copenhagen, Denmark) used were: physiologic salt solution (negative control); house dust mite (30 BU/mL); storage mite (1 NU/mL); grass pollen (30 BU/mL); birch, alder and hazel-nut pollen (30 BU/mL); fungi (*Aspergillus fumigatus*, *Cladosporium herbarium*, *Penicillium notatum*, *Botrytis cinerea*) (0.05 mg/mL); hair of cattle, horse, swine, sheep, dog and cat (30 BU/mL); histamine chloride (positive control): 0.01, 0.001, and 0.0001 mg/mL respectively. A swine and poultry dust extract (0.01, 0.1, 1, and 10 mg/mL respectively) were manufactured at the General Clinical Laboratory of the Elkerliek Hospital in Helmond. Extracts were stored at 5-8 °C until use. Extracts were dissolved in a physiological salt solution (pH 7.4). After 20 minutes a possible swelling of the skin at the injection site was measured. The diameter of the swelling was defined as the mean of the largest wheel diameter and that perpendicular to it in mm. From investigations of Brand et al. (1993) with the skin test against house dust mite and other allergens in patients with chronic nonspecific lung disease, a swelling $\geq$ 7 mm gave the best diagnostic value for symptomatic allergy. We also used this cut-off point in our study.

In serum, a screening test to detect IgE antibodies against a combination of several inhalation allergens was executed (Phadiatop®, Pharmacia, Uppsala, Zweden). When a positive test result was obtained, specific IgE-antibodies were determined. Furthermore, a screening test was performed against a combination of the following allergens: horse dandruff, cattle dandruff, goose and chicken feathers (PAXI®, Pharmacia, Uppsala, Sweden).

For dust and endotoxin exposure, two study periods were chosen, one in autumn (November 1993) and one in spring (April 1994). A spring and autumn period was chosen because temperature and relative humidity have consequences for the presence of dust and endotoxin particles in the air. Every study period had a length of seven days in which occupational activities and free days were recorded in a log-book. The unit of time recording was a quarter of an hour.

Peak Expiratory Flow (PEF) measurements were executed with a Wright Peak flow mini-meter (Clement Clarke International Ltd., England). Every participant was equipped with his own Peak flow mini-meter for the complete study period. The PEF measurement was executed in a standing position, the participant was instructed to take a deep breath and to strongly expire in the peak flow mini-meter. Every measurement was performed three times, the highest measured PEF value (expressed in L/sec) was recorded.

Four PEF measurements were executed per day: in the morning after waking up, around lunch time, in the afternoon, and just before bed time. Amplitude percent mean was chosen as a variability index (8, 9): 100% x (highest reading - lowest)/ mean reading.

In the morning of the first day of a study period every participant was equipped with an air sampler (Ametek/Du Pont® High Flow Air sampler P2500, Mansfield & Green, Florida, U.S.A.). The air sampler sampled for approximately 8 hours during the day, with a constant air velocity (120 L/hour). The air is filtered through a Whatman glass microfibre filter (GF/A, diameter 25 mm, pore size 1 μm, Whatman Int. Ltd., Maidstone, England). The filter was weighed preceding the installation in the air sampler.
Endotoxin concentration in the dust on the filter was determined with a chromogen version of the *Limulus amoebocyte* lysate assay (COATEST® Endotoxin; Chromogenix, Mölndal, Sweden). Using a standard curve, determined using a standardized endotoxin-solution (*Escherichia coli* 0111:B4), the endotoxin concentration was established. Endotoxin was measured in the General Clinical Laboratory of the Elkerliek Hospital in Helmond.

Differences in categorical variables between professional groups were analyzed using the Fisher exact test, or when appropriate with the χ^2 test. Differences in lung function values between professional groups were corrected for smoking, age, length, and gender in a multivariate covariance analysis. Differences in mean dust and endotoxin concentrations between professional groups and between study periods were analyzed in a multivariate Repeated Measures Analysis of Variance.

RESULTS

A small (0 - 20%) percentage of the veterinarians were sensitized against allergens in the skin test. With respect to the lowest concentration of swine dust, there was an indication that relatively more swine practitioners were sensitized than cattle, poultry, small-animal practitioners and the non-practitioners.

There were no significant differences between professional groups with respect to prevalence of increased IgE antibodies against house-dust mite, cat dandruff, dog dandruff, grass pollen and pollen of wild birch in veterinarians with a positive test result in the Phadiatop® screening (Table 1).

Table 1. Veterinarians (in % of the veterinarians within a professional group) with IgE antibodies against specific allergens in Phadiatop ® positive reactors, by professional group.

	Swine	Cattle	Poultry	Small Animals	Other
	n=21	n=21	n=20	n=20	n=20
Phadiatop positive reactors	24	10	25	30	25
House dust mite	24	10	20	20	10
Epithelial layers cat	0	0	5	5	5
Dog dandruff	5	0	0	0	0
Grass pollen	5	0	10	10	10
Birch pollen	0	0	5	5	5

Furthermore, determination of IgE antibodies against PAXI® in veterinarians showed concentrations all within reference values (< 0.35 kU/l).

Corrected for length, age, gender, and smoking, the mean FVC and FEV_1 was significantly lower in non-practitioners ($p < 0.01$) than in swine veterinarians (Least Square Means of difference (LSM_{dif}) were 630 mL and 485 mL respectively), in poultry practitioners (LSM_{dif} were 440 mL and 360 mL respectively) and in cattle practitioners (LSM_{dif} were 410 mL and 290 mL respectively). The mean FVC and FEV_1 in swine practitioners were significantly higher ($p < 0.01$) than in small-animal practitioners (LSM_{dif} were 340 mL and 350 mL respectively). Similar results were obtained when excluding the six female veterinarians from the analysis. The mean FVC and FEV_1 were significantly lower ($p < 0.01$) for smokers than for non-smokers (LSM_{dif} were 240 mL and 280 mL respectively).

There were no significant differences between professional groups in prevalence of increased bronchial hyperresponsiveness, as measured by means of a decrease ≥ 20% in FEV_1 or FEF_{25-75} during inspiration of ≤ 8 mg/mL histamine-chloride (Table 2).

Both in the spring and autumn investigation period, there was a significant lower dust and endotoxin exposure ($p < 0.001$) in the working environment of small-animal practitioners than of swine, cattle or poultry practitioners (Table 3 and 4).

Table 2. Increased bronchial hyperresponsiveness of veterinarians (in % of the veterinarians within a professional group) in different professional groups, measured by means of a decrease ≥ 20% in FEV_1 or FEF_{25-75} during inspiration of ≤ 8 mg/mL histamine-chloride.

	Swine	Cattle	Poultry	Small Animals	Other	Total
	n=21	n=21	n=20	n=20	n=20	n=102
FEV_1 ≥ 20% ↓	5	10	5	10	5	7
FEF_{25-75} ≥ 20% ↓	5	19	10	10	10	11

Table 3. Mean dust exposure (respirable dust in mg/m^3 air) in the working environment of four professional groups of practitioners, measured in an autumn and spring period

	Swine	Cattle	Poultry	Small Animals
	n=22	n=24	n=20	n=22
Autumn	2.1 [0.1 - 5.3]	1.5 [0.0 - 4.3]	1.9 [0.3 - 4.1]	0.3 [0.0 - 1.0]
Spring	1.6 [0.0 - 4.5]	0.8 [0.0 - 4.4]	1.6 [0.0 - 5.2]	0.2 [0.0 - 0.6]

[ ]: minimum - maximum

The mean dust and endotoxin exposure was significantly ($p < 0.01$) higher in autumn than in spring.

Table 4. Mean endotoxin exposure (in ng/m^3 air) in the working environment of four professional groups of practitioners, measured in an autumn and spring period

	Swine	Cattle	Poultry	Small Animals
	n=22	n=24	n=20	n=22
Autumn	26.6 [6 - 46]	21.2 [1 - 51]	27.7 [2 - 76]	2.3 [0 - 15]
Spring	22.4 [0 - 49]	17.8 [1 - 41]	20.3 [0 - 42]	2.2 [0 - 21]

[ ]: minimum - maximum

Both in the spring and autumn investigation period, there were no significant differences in mean endotoxin exposure between swine, cattle and poultry practitioners. There was a significantly ($p < 0.001$) higher mean dust exposure in the working environment of swine and poultry practitioners than of cattle practitioners.

There were no significant differences between professional groups in occurrence of a amplitude percentage mean ≥ 20% during one or more working days, corrected for age, gender and smoking (Table 5).

Table 5. Veterinarians with an amplitude percentage mean ≥ 20% in peak expiratory flow during one or more working days (in % of the total number of veterinarians within the professional group), by professional group and investigation period.

	Swine	Cattle	Poultry	Small Animals	Total
	n=23	n=21	n=20	n=20	n=93
Autumn	9	19	11	12	13
Spring	8	4	7	6	6

The proportion of practitioners with an amplitude percentage mean ≥ 20% during one or more working days was higher in autumn than in spring, especially for cattle practitioners. Poultry veterinarians had significantly ($p < 0.05$) more chronic nonspecific lung disease (CNSLD) symptoms (coughing and/or phlegm production and/or shortness of breath) than small-animal practitioners in the autumn period (Table 6).

Furthermore, swine veterinarians had significantly ($p < 0.05$) more complaints concerning sneezing, a stuffed-up nose and tearing eyes than small-animal practitioners. In the spring period, swine veterinarians had significantly ($p < 0.05$) more CNSLD symptoms than small-animal practitioners.

Table 6. (Respiratory) Complaints of veterinarians (in % of the total number of veterinarians within the professional group) during two or more working days in a week of four or more complete working days, in an autumn and spring investigation period.

	Swine	Cattle	Poultry	Small Animals
Autumn	n=22	n=26	n=19	n=23
chronic coughing	41	27	53	30
chronic phlegm	18	19	21	17
shortness of breath	14	0	0	0
sneezing/stuffed nose	50	31	33	26
tearing eyes	27	8	5	0
Spring	n=23	n=22	n=14	n=18
chronic coughing	35	18	21	11
chronic phlegm	17	18	7	11
shortness of breath	4	4	7	0
sneezing/stuffed nose	26	27	14	17
tearing eyes	4	5	7	6

DISCUSSION

An important consideration in the design of the study was that the study should consist of several different professional groups of veterinarians. This was due to the conviction that the results of the study would be of interest to all veterinarians. Therefore, five professional groups were chosen. However, the research budget allowed only for approximately twenty participants per group. With this choice, only considerable differences in prevalence between professional groups could be judged statistically significant. Therefore, the results of this study should be seen in the light of these constraints.

Only a small percentage of the veterinarians was sensitized against house dust mite, storage mite, pollen, fungi, hair of swine, cattle, horse, sheep, and dog and cat hair in the skin test. There were no indications for distinct differences in sensitization against allergens between professional groups, except for swine dust.

In 7% of the veterinarians increased bronchial hyperresponsiveness was seen. This is however not different from what can be expected in the normal Dutch population (Rijcken et al., 1987).

There were no distinct differences in basic lung function between professional groups, with the exception of total vital lung capacity and forced expiratory volume in the first second. In non-practitioners, the mean values of the aforementioned parameters were significantly lower than in practitioners. The highest mean values were observed in swine practitioners. This can be a reflection of the physical labour executed by swine practitioners. However, this could also be a reflection of the "healthy worker effect": those who "survive" under difficult occupational circumstances are "naturally selected" to keep working in their profession (Ahlbom and Norell, 1990).

The respiratory complaints of (especially) the poultry and swine veterinarians in the first survey (Tielen et al., 1996), but also during this study, do not seem to be supported by the results of the lung function and bronchial hyperresponsiveness investigations. In the anamnesis, the complaints are mostly passagère. The above mentioned respiratory complaints could possibly be caused by an irritation or inflammation of the upper respiratory tract (Rylander et al., 1989; Larsson et al., 1994), without measurable changes in lung function and occurrence of increased bronchial hperresponsiveness. An other possible explanation for the respiratory complaints observed is the fact that not immediately after or during occupational activities lung function measurements could be performed. However, in this case, no great emphasis should be put on this argument because the results of PEF measurements before, during and after occupational activities gave no indication for increased bronchial hyperresponsiveness.

The results of the skin test and determination of allergen specific antibodies suggest that the respiratory complaints by veterinarians are probably not related to allergy.

In general, as long as there are no proper internationally recognized limits for exposure to dust and endotoxins, one has to aim at minimum exposure. The exposure of inspirable dust was distinctly higher in the autumn than in spring in the working environment of veterinarians, which is consistent with the findings of Preller (1995) in a study with 200 swine farmers. The highest dust exposure was measured for swine and poultry practitioners. Dust exposure was similar or slightly lower for swine practitioners compared to measurements in the working environment of swine farmers (Clark et al., 1983; Attwood et al., 1986; Christensen et al., 1992; Preller, 1995). Dust exposure of poultry farmers (Clark et al., 1983) was comparable with our findings for the poultry practitioners. Swine, poultry and cattle practitioners have a distinctly higher dust exposure than small-animal practitioners. Additionally, endotoxin exposure was considerably higher in autumn than in spring, which is confirmed by the findings of Preller (1995). The endotoxin exposure was slightly lower in our study than those measured for swine farmers (Christensen et al., 1992; Preller, 1995). This may be a real difference, but it is also possible that this is due to a difference in technique to measure endotoxin concentration (one-point measurement versus kinetic measurement).
Swine, poultry and cattle practitioners have a distinctly higher dust exposure than small-animal practitioners. In the study of Preller (1995), swine farmers spent 4 to 5 hours in animal buildings per day. Due to the fact that the large-animal practitioners spent approximately 3 hours per day in animal buildings, the total endotoxin exposure may have been similar to swine farmers.

In the autumn and spring period there was an indication for a distinct abnormal lung function (amplitude percent mean $\geq$ 20%) in respectively 13% and 6% of the practitioners on one or more of the working days.

However, this is not different from a Dutch reference population of persons without asthma, without chronic respiratory symptoms and no smoking habits (Quackenboss et al., 1991). As with the results from the histamine provocation test in the medical examination, the PEF measurements gave no indications for an increased occurrence of bronchial hyperresponsiveness in veterinary practitioners.

ACKNOWLEDGEMENTS

Financial contributions of the Royal Dutch Society of Veterinary Science (KNMvD), Movir, VVAA, Dix en Co, Crediet en Effecten Bank, the Swine, Cattle and Poultry Veterinary Medicine groups of the KNMvD, The Animal Health Service in the Southern Netherlands, and the personal contribution of the participants made this study possible.

The authors thank Mrs. Herma Jansen-Hekman for help with the lung function investigations, the skin test and the bronchial hypersensitivity investigation at the Elkerliek hospital in Deurne. In the General Clinical Laboratory of the Elkerliek Hospital in Helmond, determination of IgE antibodies and endotoxin was executed. Phadiatop® and PAXI® were placed gratuitously at our disposal by Pharmacia, Uppsala, Sweden.
Glaxo B.V. (Zeist, The Netherlands) is acknowledged for putting Wright Peak Flow mini-meters gratuitously at our disposal.

The Board of the directors of the Elkerliek Hospital in Deurne and Helmond are thanked for putting the hospital and it's organisation at our disposal. They made a huge contribution to the success of this study.

A special word of thanks and appreciation for the participating veterinarians who made this study possible. They contributed a considerable amount of time and effort to finish this project successfully.

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A SURVEY OF PHYSICAL INJURIES RECEIVED AT WORK BY AMERICAN SWINE VETERINARIANS

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The objectives of our study were to document and evaluate the health hazards that swine veterinarians might encounter as they work with swine in confinement buildings. A specific assessment was needed because swine veterinary medicine differs from other types of veterinary work due to the veterinarians' exposure to confinement facilities. Hazards swine veterinarians specifically encounter include injuries from contact with hogs in high densities and close quarters, exposure to poor air quality of confinement facilities, and exposure to high noise inside these facilities. We achieved a response rate of 65% for a seven page questionnaire we mailed to the 1435 members of the American Association of Swine Practitioners (AASP). The five highest reported physical injuries were: 1) needlestick injuries (73%), 2) pain from repetitious motions (51%), 3) injuries from handling swine post-mortem (36%), 4) back problems associated with lifting or moving swine (31%), and 5) hot or cold weather-related problems (30%). Twenty-eight percent of swine practitioners were involved in a vehicle accident while working and twenty-two percent have a diagnosed hearing impairment.

Swine practitioners need to be more aware of the hazards associated with their work. They should adopt preventive procedures to protect their own health as well as providing a good example to those with whom they work.

INTRODUCTION

Paralleling, yet possibly lagging, the increased interest swine veterinarians have for the impact swine confinement has on swine health and productivity they are also increasingly interested in the effect their work environment may have on their own health. Veterinarians are exposed to many hazardous situations in their daily work; some being unique to their work in confinement buildings. They can be harmed by physical contact with hogs, by the poor air quality of confinement facilities, and the elevated noise levels inside these facilities. Although other studies have investigated the occupational health of veterinarians, there is no specific information about the prevalence of injuries to swine practitioners. Therefore, we designed a national survey to identify hazards which swine practitioners have experienced and to determine their frequency. This paper reports and comments on the physical injuries they experienced. From the information collected we hope to heighten swine practitioners' awareness of these hazards and educate others, e.g., their clients, who may be similarly exposed.

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METHODS AND MATERIALS

We surveyed all members of the American Association of Swine Practitioners (AASP) who had a United States address. Members were mailed a survey packet consisting of a cover letter, a seven page questionnaire, and a return self-addressed envelope. Two months later a second mailing, similar to the first, was sent to all nonrespondents. The deadline for return was three months after the second mailing.

Survey design methods and procedures were similar to that recommended by Dillman (1978). The information presented on physical injuries was part of a larger survey investigating the occupational hazards experienced by swine veterinarians. In the full survey, questions were categorized as physical injuries, allergic or irritant reactions, chemical exposures, and infections. A separate category, entitled preventive measures, was included to assess hygiene practices and the use of personal protective equipment. We also asked demographic questions to obtain a description of the respondents. In all, we asked 47 questions, related solely to their work with swine, and the opportunity for comments was provided on the last page. The questionnaires were coded for confidentiality and to aid in the mailings and data entry process. The survey was pretested on eleven AASP members in North Carolina.

The responses received were entered in the computer program, Epi Info Version 6 (Dean et al., 1994) and a data entry check program was incorporated to minimize errors. Simple frequency calculations were performed. Calculations for measures of association between health hazards and employment types and between health hazards and sex were performed using contingency tables. P-values with one degree of freedom are given for the Yates-corrected chi square formula for small sample sizes, except where stated otherwise. Stratified Mantel-Haenszel analysis was applied in some cases to examine confounding by years in practice and age.

RESULTS

Of the 1435 surveys mailed we received 936 (65.2%) responses. Of these, 82 respondents did not complete the survey because they felt that the questions were not relevant to their employment situation. These respondents were included only in the overall statistics of sex and employment type but were excluded from the majority of the analyses. The average age and years of employment by sex of respondents is detailed in table 1. The rank order of facilities visited by veterinarians was similar for males and females, table 2.

Table 1. Mean age and years of employment by sex of respondents

	Females	Males
Number, Percentage Responding	58, 6.2%	878, 93.8%
Mean Age, Years ± SD	34.8 ± 6.2	43.3 ± 11.1
Mean Employment, Years ± SD	8.6 ± 6.5	18.9 ± 11.1

Seventy-three percent of respondents experienced at least one needlestick injury during their career, table 3. In the past 2 years, females had an average of 4.3 (±5.2) and median 2.5 needlesticks while males had an average of 2.8 (±5.7) and median 2 needlesticks (Kruskal-Wallis H test for two groups: $p \leq 0.013$).

Of the 586 respondents reporting a needlestick injury in the past 2 years, vaccines were the most common exposures (40%). Swine blood (37%) was the second most common exposure followed by antibiotics (35%) and prostaglandins (1%). Ivermectin and clean or empty needles constituted most of the remaining 8% of needlestick exposures reported.

Adverse effects from needlestick injuries included pain, local swelling, hematoma, infection, superficial abscess, and cellulitis. The erysipelas vaccine was the most commonly cited agent for causing an adverse effect, followed by LA 200® and APP Bacterin®.

Table 2: Types of facilities visited by respondents by sex.

	Females number	Females percentage	Males number	Males percentage
Mostly confinement facilities	27	57.4%	541	69.5%
Mostly outdoor facilities	13	27.7%	159	20.4%
Confinement facilities only	6	12.8%	63	8.1%
Outdoor facilities only	0	0%	1	0.1%
50% Outdoor facilities and 50% Confinement facilities[a]	1	2.1%	14	1.8%

[a]This was not a choice offered on the survey but was volunteered by some respondents.

Table 3. Distribution of Injuries by Sex

	Females (%)[a]	Females N[b]	Males (%)[a]	Males N[b]	P
INJURIES					
Needlestick Injury	65	49	73	794	0.301
Percentage of injured that had adverse effect	41	32	36	577	0.707
Back problems	41	49	31	793	0.189
Lost work time	5	20	17	263	0.217[c]
Pain from repetitious motions	49	49	51	790	0.870
Major swine-related injury	14	49	12	793	0.862
Hospitalized for swine-related injury	0	49	2	795	0.579
Percent of hospitalized that required surgery	n/a	n/a	59	17	n/a
Equipment injury	22	49	15	794	0.241
Handling swine post-mortem	27	49	36	794	0.213
Heat or cold-related problems	31	49	30	792	0.909
Vehicle accident while working	16	49	29	794	0.090
Diagnosed hearing impairment	2	49	23	793	0.004

[a]Percentages rounded to nearest whole number
[b]Total number responding to question
[c]Fisher exact test

Thirty-one percent of respondents experienced back problems as a result of lifting or moving swine. Pain was mild for 45.4%, moderate for 37.8%, and severe for 16.8% of the 262 respondents. We did not ask how many back-injury events these data represented.

Fifty-one percent of respondents reported pain from occupationally-related repetitious motions. The 2 most reported activities were bleeding swine and performing frequent injections. Kneeling, bending over, or squatting were the motions causing pain associated with bleeding swine. Sore wrists, elbows, and blistered fingers were caused by performing frequent injections using a pistol grip syringe. Arthritis, tendinitis, bursitis, past knee injuries, and being "out-of-shape" were pre-existing conditions reported that contributed to the pain involved in these activities. Years in practice, which ranged from 0-49 years, did not ($p=0.152$) affect the response.

Twelve and a half percent of respondents never suffered a major swine-related injury, defined as an illness or injury requiring medical treatment either by a physician or self-administered, excluding those requiring only topical antibiotics. Years in practice was not ($p=0.118$) associated with an injury. The percentages of respondents who reported each type of injury are listed in table 4. The variety of treatments included self-administered antibiotics, wound dressing, stitches, time, and bed rest.

Table 4. Percentage of respondents who reported a major swine-related injury (N=842)

Other than listed injury[a]	6.4%[b]
Bite	3.2%
Stepped on	2.0%
Crush	1.8%
Gore from boar tusk	0.8%
No injury reported	87.5%

[a]Includes injuries occurring as a result of sows colliding with the veterinarian, knife injuries, lacerations, back strain, and knee injuries associated with attempting to restrain the pig.
[b]Percentages do not sum to 100 because each respondent may have reported more than one injury

Of the males hospitalized for a swine-related injury, 11 (58.8%) required surgery. Surgery types listed were 2 knee surgeries, 1 bilateral carpal tunnel surgery, 1 hand surgery, 3 laminectomies, one cervical decompression, and 1 wound debridement.

One hundred and thirty-one (15.5%) respondents reported being injured by equipment while handling swine or working in swine houses. The types of injuries can be grouped into 4 main categories listed in decreasing occurrence:

1) injuries from gates and sow chutes,
2) injuries from hog snares,
3) injuries from overhanging objects, and
4) electrical shock injuries

Injuries from gates and sow chutes were mostly minor bruises and pinched fingers but more severe lacerations and crushed fingers and hands were also reported. Hog snare injuries were mainly head injuries. Injuries from overhanging objects included equipment such as augers, fans, ventilation systems, feed delivery equipment, and heat exchangers. Six injuries were reported as a result of electrical shock from either wires, heat lamps, or heaters.

While 802 (95.1%) respondents euthanise swine, only 7 males (0.9%) and no females reported being injured while euthanising swine. One male bruised his shin in the process of delivering a blow to the head of a pig. Three jabbed their own hands when using an injectable solution such as barbiturates, one experienced an adverse reaction to phenobarbital when the bottle broke, and one reported mental stress as a result of being reported for animal cruelty.

Thirty-six percent of respondents reported being injured from handling swine post-mortem, table 5. Approximately two-fifths of the knife wounds and three-quarters of infections required some form of medical treatment. More than half of the other exposures listed also required medical treatment. Only 2 of the 17 back injuries required medical treatment. Fifty-two percent of the 355 injuries reportedly did not require medical treatment.

Table 5. Percentage of respondents who were injured while handling swine at post-mortem (N=843)

Knife wound	33.7%[b]
Infection	4.7%
Back injury	2.0%
Chemical exposure	0.8%
Other than listed injury[a]	0.7%
Burn	0.2%
No injury reported	64.2%

[a]Includes burns, one *Salmonella spp* exposure, one rabies exposure, one *Klebsiella pneumoniae* exposure, and one band saw laceration.
[b]Percentages do not sum to 100 because each respondent may have reported more than one injury

Of 841 respondents, 13.7% reported problems related to the cold, 5.6% reported problems related to heat, and 10.9% reported problems related to both the cold and heat. Cold-related problems reported consisted mostly of cold or numb extremities but approximately one-quarter of the cold-related problems were frostbite of the fingers and ears. Frequent colds and flu were also reported. High temperatures caused heat exhaustion in approximately one-third of those who reported heat-related problems. Other problems included fatigue, dehydration, overheating, dizziness, and one heat stroke.

DISCUSSION AND CONCLUSIONS

Needlestick injuries

Swine veterinarians may accidentally jab themselves with a needle when they are uncapping or recapping the needle, injecting animals, or filling a syringe, a process involving motions similar to recapping a needle. The percentage of practitioners who reported having suffered a needlestick injury (64% females and 73% males) is similar to the prevalence of percutaneous injury, mostly syringe needles, suffered by nurses, 64.7%, and housestaff, 74.1% at a Philadelphia hospital (Rattner et al., 1994).

For the most part, exposure to products used for swine vaccination by healthy practitioners did not represent a serious health hazard. Based on one report, the modified live bacterial products for

Pasteurella, erysipelas, and *Bordetella* are not associated with human health problems (Heidelbaugh et al., 1989). However, individuals who are immunosuppressed have a greater risk of harm from exposure to many of the live bacterial or viral agents (Heidelbaugh et al., 1989). Hypersensitivity is an adverse effect that can occur to antigens or antibiotics used in vaccines, bacterins, or diagnostics (Heidelbaugh et al., 1989). In our survey, fewer than 2% (N=407) of the respondents experienced needlestick injuries with exposure to prostaglandins in the past 2 years. This is a very low prevalence, however, it is a major concern for pregnant females because of its abortive effect on the foetus. Besides accidental injection, prostaglandins can be absorbed through the skin (Gold & Beran, 1983). Therefore, pregnant females should avoid all direct physical exposure to this drug.

In human health care, a needlestick injury is particularly worrying because of the possibility of contracting bloodborne pathogens particularly hepatitis C and B and Human Immunodeficiency Virus (HIV). Although the risk of infection with HIV is only 0.4% or less (Waters et al., 1994), needlestick victims have the worry of not knowing whether or not they have contracted an untreatable fatal disease for the six months it takes for a definitive diagnosis. Fortunately, swine practitioners are not occupationally exposed to these diseases, however, they could feasibly contract brucellosis, tetanus, and streptococcosis or staphlococcosis from needlesticks.

To minimize the risk of needlesticks, other drug delivery and blood collection systems should be investigated. Also, the current systems for handling sharp instruments should be improved through safer use of the existing systems and redesigning the current systems to make them safer. A multi-dose syringe with retractable needle should decrease needlestick injuries while administering vaccines, antibiotics and others, however it may be cost prohibitive. Compressed-air powered guns that shoot "bullets" of antibiotics are available (BallistiVet Inc., PO Box 10812 White Bear Lake, MN 55127). These guns would eliminate needlestick injuries and should decrease repetitive motion disorders from frequent injections, however, they introduce a new, and so far unquantified, risk inherent when guns are used. Sharps disposal devices, as currently used in laboratories and hospitals, are not suited for use in swine barns because they are bulky and designed to sit on a tabletop. Even when used in human hospital settings, sharps disposal containers have been implicated in needlestick injuries when they are improperly sited or people are inadequately trained (Weltman et al., 1995). Similarly, recapping devices used in human health care are impractical for swine practitioners because they are also bulky, and usually fixed to a tabletop. Practitioners could decrease the risk of injury from needlesticks by wearing thick (0.83 mm) latex gloves which provides dexterity and tactility comparable to the bare hand yet resist needle puncture (Nelson and Mital, 1995). Wearing a single regular-thickness latex glove decreases the volume of blood transferred by needlestick 46%-63% (Mast et al., 1993). Such a reduction could be a important decrease in risk when working with animals known or suspected of carrying disease transmissible by needlestick.

<u>Repetitive motion disorders</u>

Over half the respondents experienced pain associated with performing frequent injections and/or bleeding swine. If the recovery time between these activities is insufficient, and the repetitious action is compounded with forceful and awkward postures, the practitioner is at risk for developing a repetitive motion disorder (Williams and Westmorland, 1994).

Many practitioners may be experiencing mild forms of trigger finger or trigger thumb, whereby extending or flexing the digit is halted momentarily and completed with a jerk. This is caused by repeated, localized, contact stresses from using a pistol grip syringe or syringe respectively. More severe cases may result in tenosynovitis (inflammation of a tendon sheath) in the finger or de Quervain's syndrome (a special case of tenosynovitis in the thumb)(Williams and Westmorland, 1994). Practitioners may also be at risk for carpal tunnel syndrome, caused by compression of the median nerve in the carpal tunnel of the wrist. Directly comparable data are not available, however, Tanaka and others (1995) reported that of the `127 million "recent workers" in the US who worked during the 12 months prior to the survey, 1.47% self-reported they had suffered from carpal tunnel syndrome. At colder temperatures, the risks are greater because a person exerts more force than usual to prevent an object from slipping out of the hand (Williams and Westmorland, 1994). Repeated kneeling may cause bursitis of the knees (Ehlers et al., 1993). Chronic back strain can result from repetitive bending and lifting.

Generally, symptoms do not progress to these levels because the activities do not occur on a daily basis. This gives the muscles and joints time to recover. These activities do cause temporary pain and soreness that can be partially alleviated through tool design, physical conditioning, and/or work-hardening (Williams and Westmorland, 1994). To decrease pain in fingers and thumbs, practitioners should periodically switch the hand or fingers used. Sore wrists should be kept at a neutral position to decrease nerve compression. Symptoms of nerve compression, often worse at night, may be relieved with the aid of a wrist splint (Williams and Westmorland, 1994). Knee pads will decrease the amount of direct pressure on the knees. If possible, practitioners should alternate between squatting, kneeling and bending over to prevent back strain. Ideally, pain associated with activities involving repetitive motions can be alleviated by rotating job duties. If this is not an option, frequent short breaks to stretch muscles are recommended instead (Mackinnon & Novak, 1994).

Swine-related injuries

Swine were involved in very few injuries, but, as expected, there was an increase in prevalence as the years in practice increased. Hospitalization for a swine-related injury was rare. There was an increased prevalence for hospitalization in males as the years in practice increase. No females reported being hospitalized but one cannot say that males have a higher risk because: 1) no females in this study had been in practice long enough and 2) many more female practitioners would be needed to assess their true risk.

Swine-related injuries can be avoided by working with someone and anticipating the hog's reactions. Except for a few reported bites, most injuries were acquired indirectly from hogs. Accidents occurred when the practitioner happened to be in the flight path of the hog, in which case, it ran either between the legs or directly into the practitioner. When moving hogs, cutting boards protect peoples' legs as well as making the hogs easier to move.

Back pain is a common occupational illness accounting for about one quarter of workers' compensation claims in the US. In a survey of US "workers" about 17.6% suffered back pain for a week or more during the previous 12 months (Guo et al., 1995). Back problems from lifting or moving swine can be complicated hazards to prevent. They result from a combination of risk factors including the weight of the pig, fatigue and overexertion, and posture when lifting or moving pigs (Waters and Putz-Anderson, 1994). A worksite analysis of the tasks causing back problems should be performed. Generally, it is best to lift by extending the knees, rather than the back, without twisting, and keep the load close to the body (Mackinnon & Novak, 1994).

Equipment injuries

Many equipment injuries were minor cuts and bruises from overhead objects, but were either repeated enough or serious enough to be remembered. The prevalence of this injury type is probably underestimated because the lesser injuries are less likely to be reported. Prevention begins with being aware of the potential hazards. Practitioners should look around and be aware of their potential hazards. They should suggest to their clients that they use warning signs on low hanging objects and properly shield all fans. Hog snares caused a number of head injuries. Presumably they occurred when the snare slipped from the helper's hand and hit the practitioner. The seriousness of the injuries were not assessed.

Post-mortem injuries

Knife wounds from post-mortem injuries usually required some type of medical treatment. Wearing cut-resistant gloves incorporating fiber such as Kevlar® or Spectra® should minimize these injuries as well as infections. An evaluation is suggested of the techniques involved in examining swine post-mortem. Perhaps modification of work practices can prevent these injuries.

Hot and cold-related problems

Prevention of heat emergencies is through recognition of symptoms and prevention of dehydration. Heat exhaustion is characterized by excessive sweating, headache, dizziness, muscle weakness, and nausea. Some of the individual risk factors for heat emergencies are dehydration, heavy clothing, prolonged exertion, aging, and alcoholism (Bross et al., 1994).

The heat index is a good indicator of potentially dangerous situations. The heat index, often given in weather reports, is a measure of how hot it feels when relative humidity is combined with the effects of air temperature. An individual may begin to feel fatigued when working at 80°F (26.7°C); at greater than 90°F (32.2°C) an individual may be at risk for heat exhaustion (Bross et al., 1994).

To prevent dehydration, eight ounces of water, or another fluid that replenishes electrolytes, should be consumed before working and moderate amounts should be consumed every 20 minutes during activities in heat (Bross et al., 1994).

Cold temperatures were responsible for most of the problems related to temperature extremes. In ambient temperatures of 46.4°F (8°C) and lower, the risk is high for frostbite on the face, hands, or feet (Anttonen, 1993). Always wearing gloves, earmuffs, and thermal socks will decrease the risk of frostbite to these areas. Glove warmers might also help if carried in the pockets. Wearing a hat will decrease the majority of body heat loss experienced. Face masks should be worn in windy conditions. Clothing should be worn in layers to make it easier to adjust from working outside to working inside a swine building.

There are some weaknesses in this study that might bias the results. Inherent in a retrospective survey is a recall bias that can lead to either an over- or underestimation of the prevalence of health hazards in swine practitioners. Additionally, selection bias may be introduced by limiting the survey to US members of the AASP. Interviewer bias could result during interpretation of information reported by study participants. For example, some types of employment were inferred by the investigator based on information from the respondent or from mailing addresses. However, consistent interpretations were obtained by having only one person involved in the data entry process, using uniform criteria.

The survey also did not originally take into account employment types other than private practice. Although most practitioners fell into the listed categories of private practice, some have responsibilities in swine production management, research and development, nutrition, and/or regulatory functions.

Although no relative risk differences were found among employment types for health hazards, except for retired males, it is difficult to accurately assess this risk. Few respondents were in employment types other than private practice. Many nonrespondents might be in these types of practices. They probably excluded themselves because the questionnaire was geared towards those in private practice and there was no space provided for reporting a practice other than the ones listed.

The AASP members in these groups that did respond to the survey probably had more contact with swine than those who did not. This would tend to bias any differences seen among employment types towards the null.

Measures of association among employment types were not stratified by sex because any observations in females among practice types would be hindered by the small data set. Additionally, any reported relative risks of males versus females, calculated using contingency tables, must be considered rough estimates because of the survey had so few females.

The authors thank the American Association of Swine Practitioners for their support of this study.

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Printed at the University of Edinburgh

SOCIETY FOR VETERINARY EPIDEMIOLOGY AND PREVENTIVE MEDICINE

APPLICATION FOR MEMBERSHIP

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Please enclose the membership fee (£10 sterling) along with this application form. Overseas members without British bank accounts are requested to pay 2 - 3 years in advance. Cheques should be in £ sterling and drawn from a British bank. British members should pay future dues by standing order (forms are available from the Secretary or Treasurer).

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Agricultural Economics Unit
University of Exeter
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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. Membership is conditional on the return to the Secretary of a completed application form and a subscription equivalent to the rate for one calendar year. Subsequent subscriptions fall due on the first day of May each year.

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 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. 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 and 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; November 1994