SOCIETY FOR VETERINARY EPIDEMIOLOGY AND PREVENTIVE MEDICINE

Proceedings of a meeting held at
the University of Edinburgh on
the 10th and 11th of July 1984

Edited by M.V.Thrusfield

ISBN 0 948073 03 9
Society for Veterinary Epidemiology and Preventive Medicine: Proceedings of a meeting held at the University of Edinburgh on 10th and 11th July, 1984.

ACKNOWLDEGEMENTS

Financial support for the printing of these proceedings was given by Beecham Animal Health, Duphar Veterinary Ltd., Hoechst U.K. Ltd., Smith Kline Animal Health Ltd. and the Wellcome Trust.

Mrs. M. Clater, of the Department of Animal Health, University of Edinburgh, supplied secretarial assistance for the production of the proceedings.

CONTENTS

LIST OF PARTICIPANTS

D.J. Bates	V.I. Centre, Kendal Road, Harlescott Road, Shrewsbury.
R.A. Bell	M.A.F.F., Central Veterinary Laboratory, New Haw, Weybridge, Surrey.
J.M. Booth	Milk Marketing Board, Veterinary Laboratory, Cleeve House, Lower Wick, Worcester.
G. Caldow	3F1, 5 West Crosscauseway, Edinburgh.
M.J. Clarkson	Department of Veterinary Preventive Medicine, University of Liverpool, Leahurst, Neston, Wirral, Merseyside.
A.J.C. Cook	Garth Veterinary Group, 80 Main Street, Beeford, N. Humberside.
D. Cordes	Virginia Maryland Regional College of Veterinary Medicine, Virginia Tech., Blacksburg, Virginia 24061, U.S.A.
J. Corkish	V.I. Centre, Kendal Road, Harlescott Road, Shrewsbury.
N. Coulson	RAVC Laboratory & Stores, Gallwey Road, Aldershot, Hants.
P.J. Cripps	Department of Veterinary Medicine, School of Veterinary Science, University of Bristol, Langford House, Langford, Avon.
P.E. Curtis	Sub-Department of Avian Medicine, University of Liverpool, Leahurst, Neston, Wirral, Merseyside.
J.C. Cuthbertson	Department of Clinical Studies, A.D.R.A., Moredun Institute, 408 Gilmerton Road, Edinburgh.
D.L.G. Danson	Duphar Veterinary Ltd., Duphar House, Gaters Hill, West End, Southampton.
G. Davies	Epidemiology Unit, M.A.F.F., Central Veterinary Laboratory, New Haw, Weybridge, Surrey.
A.I. Donaldson	Animal Virus Research Institute, Pirbright, Woking, Surrey.
R.M. Edelsten	C.T.V.M., Veterinary Field Station, Easter Bush, Roslin, Midlothian.
A.J. Elliott	M.A.F.F., Veterinary Investigation Centre, Quarry Dene, Weetwood Lane, Leeds.

D.J. Evans	M.A.F.F., Government Buildings, Burghill Road, Westbury-on-Trym, Bristol.
G.S. Ferguson	Department of Animal Health, Veterinary Field Station, Easter Bush, Roslin, Midlothian.
W.P. Gardiner	Department of Mathematics, Glasgow College of Technology, Cowcaddens Road, Glasgow.
G. Gettinby	Department of Mathematics, University of Strathclyde, Livingstone Tower, 26 Richmond Street, Glasgow.
C.J. Giles	Department of Medicine, Royal Veterinary College, Hawkshead House, Hawkshead Lane, North Mymms, Hatfield, Herts.
E.A. Goodall	Department of Agricultural Biometrics, Agriculture & Food Science, The Queen's University, Newfordge Lane, Malone Road, Belfast.
J.S. Gray	Department of Agricultural Zoology, University College, Dublin.
S.A. Hall	M.A.F.F., Chief Scientist's Group, Great Westminster House, Horseferry Road, London.
Miss C.N. Hebert	Epidemiology Unit, M.A.F.F., Central Veterinary Laboratory, New Haw, Weybridge, Surrey.
W. Holland	The Avenue Veterinary Hospital, 33 St. Peter's Avenue, Kettering, Northants.
K.S. Howe	Agricultural Economics Unit, Lafrowda House, St. German's Road, Exeter.
S.C. Hutchins	M.A.F.F., Palatine House, 100 Lancaster Road, Preston.
D.E. Jacobs	Department of Microbiology & Parasitology, Royal Veterinary College, Hawkshead House, Hawkshead Lane, North Mymms, Hatfield, Herts.
J.M. Kelly	Department of Animal Health, Veterinary Field Station, Easter Bush, Roslin, Midlothian.
P. Kitching	Animal Virus Research Institute, Pirbright, Woking, Surrey.
M.H. Lamont	M.A.F.F., Veterinary Investigation Centre, Madingley Road, Cambridge.
L.P. Lloyd-Evans	Smith Kline Animal Health Ltd., Cavendish Road, Stevenage, Herts.
S. Lucey	Institute for Research on Animal Diseases, Compton, Newbury, Berkshire.

G. McIlroy	Epidemiology Unit, Department of Agriculture, Veterinary Research Laboratories, Stormont, Belfast.
W.P. McLaren	RAVC Laboratory & Stores, Gallwey Road, Aldershot, Hants.
J.S. McLauchlan	Hohenstaufenstrasse 42, 7141 Moglingen, W. Germany.
W.B. Martin	A.D.R.A., Moredun Institute, 408 Gilmerton Road, Edinburgh.
G.B.B. Mitchell	West of Scotland College of Agriculture, V.I. Department, Auchincruive, Ayr.
J.J. Nagle	Ballyclough Cattle Breeding Society, Ballyvorisheen, Mallow, Co. Cork.
P.S.L. Ong	1426, Pasir Pinji, Ipoh, Perak, Malaysia.
G. Paton	Department of Mathematics, University of Strathclyde, Livingstone Tower, 26 Richmond Street, Glasgow.
B.D. Perry	Division of Pathobiology & Public Practice, Virginia-Maryland Regional College of Veterinary Medicine, Virginia Tech., Blacksburg, U.S.A.
H. Pharo	V.E.E.R.U., Department of Agriculture & Horticulture, University of Reading, Earley Gate, Reading.
R.W.J. Plenderleith	University of Glasgow Veterinary Practice, Whitelees Road, Lanark.
D.G. Powell	The Animal Health Trust, Equine Research Station, PO Box 5, Snailwell Road, Newmarket, Suffolk.
A.P. Power	M.A.F.F., 55 Whitehall, London.
M.J. Prince	M.A.F.F., Veterinary Investigation Centre, Bryn Adda, Penrhos, Bangor, Gwynedd.
D.G. Pritchard	Department of Bacteriology, M.A.F.F., Central Veterinary Laboratory, New Haw, Weybridge, Surrey.
S.N.H. Putt	VEERU, Department of Agriculture & Horticulture, University of Reading, Earley Gate, Reading.
G.J. Rowlands	Institute for Research on Animal Diseases, Compton, Newbury, Berkshire.
A.M. Russell	Institute for Research on Animal Diseases, Compton, Newbury, Berkshire.
R.M.Q. Sainsbury	M.A.F.F., Alma Place, Redruth, Cornwall.

R.G. Scott	C.T.V.M., Veterinary Field Station, Easter Bush, Roslin, Midlothian.
C.V. Smith	Meteorological Office, London Road, Bracknell, Berks.
Miss M.F. Stallbaumer	137 Clonmell Road, London.
M.V. Thrusfield	Department of Animal Health, Veterinary Field Station, Easter Bush, Roslin, Midlothian.
G.W. Tribe	Shamrock Farms (UK) Ltd., Victoria House, Small Dole, Henfield, Sussex.
L. Tyler	VEERU, Department of Agriculture & Horticulture, University of Reading, Earley Gate, Reading.
E.M. Varley	M.A.F.F., National Agricultural Centre, Kenilworth, Warwickshire.
A.S. Warde	MOD (AVR), Government Buildings, Droitwich, Worcs.
K.S. Warwick	M.A.F.F., 55 Whitehall, London.
W.A. Watson	M.A.F.F., Block B, Hook Rise South, Tolworth, Surbiton, Surrey.
D.A. Whitaker	Department of Animal Health, Veterinary Field Station, Easter Bush, Roslin, Midlothian.
J.W. Wilesmith	Epidemiology Unit, M.A.F.F., Central Veterinary Laboratory, New Haw, Weybridge, Surrey.
Miss P.A. Williams	Epidemiology Unit, M.A.F.F., Central Veterinary Laboratory, New Haw, Weybridge, Surrey.

OVINE EPIDEMIOLOGY AND PREVENTIVE MEDICINE

EPIDEMIOLOGICAL PROBLEMS ASSOCIATED WITH SOME DISEASES OF SHEEP

W.B. MARTIN*

Groups of animals are always liable to be involved in outbreaks of disease particularly when new animals are introduced or promiscuous mixing of groups occurs. Some diseases may be introduced with incoming animals or those within the flock may infect the incoming animals. Other diseases are present in a particular environment, so that the indigenous population builds up immunity but introduced animals may succumb.

As the economic advantages of keeping sheep have improved sheep numbers have risen. Flocks have increased in size and the total national flock has risen to over 31 million. On many farms the larger flock size has resulted in more intensive management systems being introduced, and for reasons of labour and ease of management, housing of sheep particularly before and at lambing, is being adopted increasingly.

Changes in management almost invariably bring new problems, some of which are disease problems especially where the headage is increased per unit area.

Modern flock management and the current degree of intensification would not have been possible without effective methods for the control of clostridial diseases in sheep. During the early part of this century the epidemiological problems caused by clostridial diseases were such that some farms could not breed sheep. Conquering these diseases has not only allowed successful and profitable sheep husbandry but has resulted in other problems becoming evident.

Some of the epidemiological problems associated with diseases of sheep currently occupying the thoughts of research scientists will be outlined in this paper.

Respiratory problems in sheep are a frequent cause for concern and of these pasteurellosis is the most common disease. The causal bacterium, certainly in the U.K., is Pasteurella haemolytica which is of two biotypes (A & T) and at least 15 serotypes (Fraser et al, 1982).

Each biotype is known to cause a distinct syndrome. Biotype A bacteria are commensals which live in the mucosa of the upper respiratory tract but under certain conditions these organisms multiply to cause outbreaks of pneumonia. One definite 'trigger' factor is known, namely infection with parainfluenza type 3 virus (PI3). Experimental evidence for the synergism of these 2 organisms in this disease is convincing (Sharp et al, 1978). When sheep are collected together, especially if housed, conditions are ideal for PI3 to spread and the majority of outbreaks may occur as a result of this infection allowing P. haemolytica to overcome the normal defence mechanism of

---

*Moredun Research Institute, 408 Gilmerton Road, Edinburgh EH17 7JH

the respiratory tract. However what is unknown is whether all outbreaks of acute Pasteurella pneumonia are associated with this dual infection. Can the organism alone cause serious outbreaks and if so why should the organism suddenly increase in pathogenicity? A better understanding of the epidemiological and immunological factors is required with this infection.

An entirely different form of disease is caused by the T-types of P. haemolytica. Tissue invasion by this organism results in systemic disease. Within the past few years our understanding of the pathogenesis has increased considerably (Dyson et al, 1981). It is now realised that T-types live in the tonsils of apparently healthy sheep. When disease occurs these bacteria multiply in the fauces and spread, possibly by the lymphatic route, to the lung.

What is not known is why outbreaks of this disease occur in hoggs in the autumn. What factor stimulates the rapid multiplication of this organism, apparently simultaneously, in a number of sheep with fatal consequences? No clear indication of a predisposing factor has been established depsite detailed epidemiological studies of a number of outbreaks in the border region of Scotland (Dyson et al, 1981).

Slow virus diseases of sheep have increased in importance since Sigurdsson in 1954 described slow infections of sheep occurring in Iceland. With the increase in international trade in sheep, three important slow diseases of sheep, maedi-visna, jaagsiekte and scrapie have been spread throughout the world. Our understanding of these diseases has increased considerably but gaps in our knowledge remain, some of which are related to the epidemiology of these diseases.

Jaagsiekte, or sheep pulmonary adenomatosis (SPA), is not uncommon in sheep in Scotland. Hunter and Munro (1983) found that 24% of lungs submitted for histological examination had lesions of SPA. Curiously, although the disease has been known in Britain since 1888 (Dykes and McFadyean), it is seen particularly in flocks down the east of Scotland and the border area.

No satisfactory explanation for this distribution has been given though one might suppose that the many flocks in these areas are endemically infected with the causal retrovirus and thus a high incidence is maintained. The disease seems particularly prevalent in greyface and halfbred sheep but this may reflect the more intensive systems under which these sheep are kept rather than inherent susceptibility. Nor is an explanation readily available for the lower prevalence of SPA in the intensively managed flocks in England.

Another slow virus disease which is causing concern in Britain is maedi-visna. This problem would seem to be one of recent introduction due to the importation of sheep from Europe (Markson et al, 1983). Naturally therefore initial reports of the presence of disease came from flocks of exotic sheep or where sheep had been in-contact with those from Europe.

The introduction of the MAFF Accredited Flocks Scheme will undoubtedly help to reduce the penetration of this virus infection into our national flock, but are we too late? Has this infection moved into a significant proportion of our indigenous flocks, perhaps too far to allow eradication? Is maedi-visna now an established disease which our veterinary services will require to deal with as a clinical problem in flocks in future? Or shall we find that breeds of sheep are of differing susceptibility which, together with management factors, increases or reduces the prevalence in flocks?

These intriguing epidemiological problems remain to be answered.

Abortion in sheep is a major problem which can seriously affect the economy of sheep production. The most common cause is chlamydial or enzootic abortion of ewes (EAE). Some years ago a vaccine was produced which reduced the prevalence of abortion (see review by Foggie, 1973). However, since about 1978 vaccine breakdowns have been causing concern. Experimental work has shown that strains exist which are capable of overcoming heterologous immunity (Aitken : personal communication).

Unfortunately, classification of ovine abortion strains of C. psittaci by in vitro techniques is not yet possible (McClenaghan et al, 1984) so we do not know how many antigenically-distinct types exist. At some stage in the future an epidemiological survey of the types and prevalence of C. psittaci in sheep would be of value in deciding the important strains to be incorporated in vaccines and the best means of control.

The second important cause of abortion in sheep in Britain is toxoplasma abortion. Toxoplasma gondii is an organism which can only complete a sexual life cycle in the intestinal epithelium of cats, with the production of oocysts. Oocysts passed in the faeces of the cat are highly resistant to destruction and can survive outdoors for over one year. Epidemiological studies have indicated that oocysts are an important source of infection for other animals. As no other form of Toxoplasma is quite so resistant it is thought that the oocyst is the most important means by which infection is acquired by sheep, and that contact transmission between sheep is less important. The wide dissemination of this infection within the sheep population of this country is still somewhat of a mystery. The origin and mechanims associated with transmission of infection are not clearly known but certainly the organism is capable of infecting a high proportion of susceptible ewes (Blewett, 1983).

Some additional information on the mode of transmission has come from Australia where it has been suggested that oocysts ingested by sheep may remain viable when excreted in the faeces. Sheep may thus act as contaminators of the environment, but further work is necessary if the complete epidemiological picture is to be established.

With intensive methods of husbandry has come an increase in the number of flocks of sheep which are housed. In many flocks silage feeding has been introduced and apparently concomitantly has come a rise in the prevalence of listerial encephalitis. L. monocytogenes is widely distributed in nature and it can multiply in alkaline silage in the more aerobic surface layers. However the means by which L. monocytogenes infects sheep and travels to the brain is not clearly known. Nor do all sheep which are fed contaminated silage develop disease (Grønstøl, 1979). These epidemiological problems remain to be elucidated and doubtless with the growing importance of this problem increased effort will shed light on the mode of transmission, infection and epidemiology of this disease.

In this brief review I have highlighted only some of the epidemiological problems associated with diseases of sheep. One feature of recent interest which covers a spectrum of diseases is the importance of metals and metalloenzymes in infections.

Al-Sultan and Aitken (1984) showed that high levels of iron given to mice experimentally infected with P. haemolytica of T-biotype, significantly altered their susceptibility to this organism. Could this factor be important in altering the susceptibility of sheep in the field as for example when suddenly introduced to rape?

Another clue as to the importance of micro-elements in relation to infection has been the demonstration that copper-deficient mice, though showing no clinical signs of deficiency, show an increased susceptibility to experimental infection with P. haemolytica (Jones & Suttle, 1983).

With these initial demonstrations of the association of micro-elements in disease the question arises as to their influence in altering the epidemiology of an infection. Can such factors as deficiency of some or excess of other elements alter an infectious process within a flock or herd with the development of a significant outbreak of disease?

In this short artiçle I have done no more than indicate some problems which may be of interest to the epidemiologist whose input and interest may yet help to solve these problems.

REFERENCES

Al-Sultan, I.I. and Aitken, I.D. (1984). Promotion of Pasteurella haemolytica infection in mice by iron. Res. Vet. Sci. (in press).

Blewett, D.A. (1983). Possible mechanisms of Transmission in Clinical Ovine Toxoplasmosis. Proc. Soc. Vet. Epidem. & Prev. Med., Southampton, 1983, 145

Dykes, J.R. and McFadyean, J. (1888). J. Comp. Path. & Therap., 1, 139.

Dyson, D.A., Gilmour, N.J.L. and Angus, K.W. (1981). Ovine Systemic Pasteurellosis caused by Pasteurella haemolytica Biotype I. J. Med. Microbiol., 14, 89.

Foggie, A. (1973). Preparation of vaccines against enzootic abortion of ewes. A review of the research work at the Moredun Institute. Vet. Bulletin, 43, 587.

Fraser, J., Laird, S. and Gilmour, N.J.L. (1982). A new T biotype serotype of Pasteurella haemolytica. Res. Vet. Sci., 32, 127.

Grønstøl, H. (1979). Listeriosis in Sheep. Listeria monocytogenes excretion and immunological state in healthy sheep. Acta. Vet. Scand., 20, 168.

Hunter, A.R. and Munro, R. (1983). Brit. Vet. J., 139, 153.

Jones, D.G. and Suttle, N.F. (1983). The effect of copper deficiency on the resistance of mice to infection with Pasteurella haemolytica. J. Comp. Path., 92, 261.

McClenaghan, M., Herring, A.J. and Aitken, I.D. (1984). Comparison of C. psittaci isolates by DNA restriction endonuclease analysis. Infection & Immunity (in press).

Markson, L.M., Spence, J.B. and Dawson, M. (1983). Vet. Rec., 112, 267.

Martin, W.B., Angus, K.W., Robinson, G.W. and Scott, F.M.M. (1979). Comp. Immun., Microbiol. and Inf. Diseases, 2, 313.

Sharp, J.M. (1981). Vet. Rec., 108, 391.

Sharp, J.M., Gilmour, N.J.L., Thompson, D.A. and Rushton, B. (1978). Experimental infections of specific pathogen free lambs with Parainfluenza virus type 3 and *Pasteurella haemolytica*. J. Comp. Path., 88, 237.

Sigurdsson, B. (1954). Brit. Vet. J., 110, 341.

THE EPIDEMIOLOGY OF COENURIASIS (GID)

M. F. STALLBAUMER*

Taenia multiceps is a cestode primarily of the dog but foxes and other wild carnivores occasionally act as definitive hosts. Sheep are the primary intermediate hosts but cattle and goats may also be affected. One or more cysts develop in the C.N.S. of the sheep and the life-cycle is completed when a dog ingests a mature coenurus cyst, tapeworms developing from the protoscoleces contained within the cyst. Infected sheep vary from those showing no clinical signs to those with severe neurological disturbances. The clinical condition is called coenuriasis or gid. The majority of cases are chronic and sporadic in sheep between one and two years old. Lambs usually become infected with T. multiceps eggs during their first months at grass and the metacestode cysts take about 6 months to mature, therefore, gid is unusual in lambs under six months old and it is not generally considered as a diagnosis in neurological disturbances in young lambs. The majority of cases occur as chronic, sporadic infections in sheep between one and two years old. Where contamination of the land is heavy, however, outbreaks of gid may occur and young lambs may show signs of the acute disease, though mortality is generally low (Vicary, 1979; Edwards & Herbert, 1982). The important factors determining the epidemiology of gid are summarised in Figure 1.

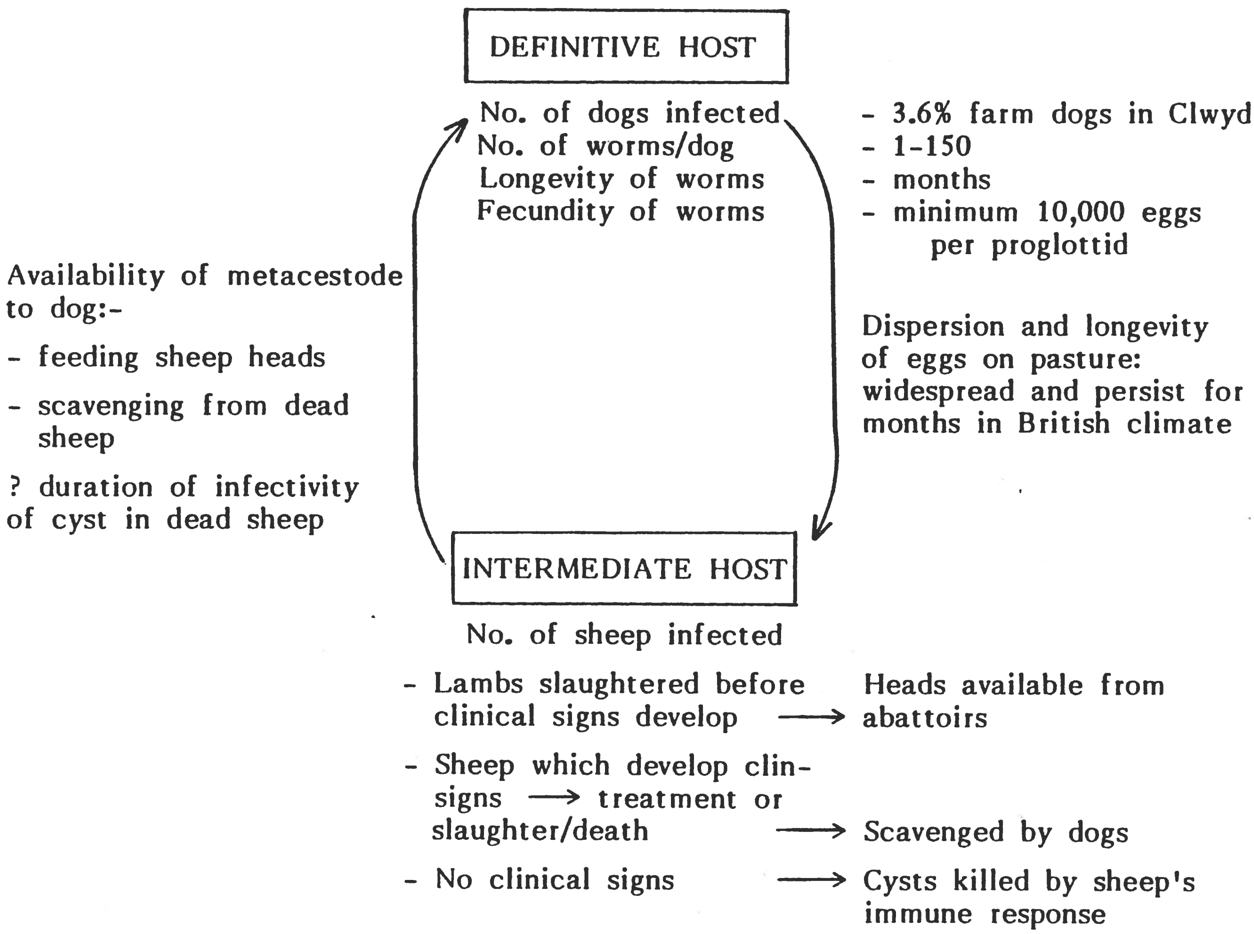


Fig. 1: Factors determining the epidemiology of gid

*Veterinary Clinical Science, University of Liverpool, Faculty of Veterinary Science, Field Station, 'Leahurst', Chester High Road, Neston, South Wirral, L64 7TE.

Surveys have recorded prevalences of T. multiceps in dogs of between 0% in East Anglia (Cook & Clarkson, 1971) and 11.4% in Dyfed (Williams, 1976), where the highest incidence of gid has also been recorded (Anon, 1980). In a survey conducted in Clwyd, Wales, by the author between 1980 and 1983, the prevalence of T. multiceps in 140 farm dogs was found to be 3.6% and 1% in 311 foxhounds. During the same period 75 cases of severe neurological disturbance in sheep were investigated at the University of Liverpool, Faculty of Veterinary Science, the majority comprising cases of gid from Clwyd. Details of the age, sex, breed and geographical distribution of these animals will be presented. Twenty seven (49%) of the 55 gid cases from Clwyd came from one farm which bordered one of the two farms where T. multiceps were found in the dogs. On both farms where T. multiceps were found the main diet of the dogs was sheep heads obtained from the local abattoir.

Sheep heads are rarely examined at slaughterhouses, therefore, the prevalence of sub-clinical gid is difficult to estimate. Edwards et al (1979) found the prevalence of cysts to be 0.5% (3 of 660 lambs) in Snowdonia. Cook (1965) found 11 (1.8%) of 630 lamb brains affected in mid-Wales and Williams (1977, quoted by Edwards et al, 1979) found a prevalence of 5.8% in Dyfed.

Sheep which develop the clinical condition are usually members of the breeding flock. They may be noticed by the farmer and either sent for slaughter or treatment may be attempted. If the sheep dies before the condition is detected, however, the head may be scavenged. Cysts probably remain infectious within the dead host's skull for a week or more (Herbert, personal communication). Foxes have been found to be infected but mature worms have not been recorded (Williams, 1976; Hackett & Walters, 1980). Some sheep apparently mount an immune response and mature metacestodes may be killed before clinical signs develop (Edwards & Herbert, 1982). Such sheep are end-stage hosts in the life-cycle. Thus mature coenuri which fail to induce clinical signs of infection are of greatest epidemiological significance since the brains of these animals are most likely to be fed to dogs thereby maintaining the life-cycle.

The distribution and longevity of eggs on the pasture are also important factors. Weather conditions in Britain are rarely lethal to eggs and viable eggs are likely to be found throughout the year (Stallbaumer, submitted for publication). The infection pressure, therefore, will depend largely on the rate of addition of eggs to the pasture and the loss of eggs through dispersion. The movements and defaecation habits of the definitive host determine the primary site of egg deposition, however, eggs appear to undergo secondary dispersion immediately after deposition, therefore, those dispersion mechanisms largely determine the distribution of eggs in the environment. These mechanisms are still uncertain but insects and birds are strongly implicated (Lawson and Gemmell, in press).

Acknowledgements

The author would like to thank Professor M. J. Clarkson for his supervision with this work and the Agricultural and Food Research Council for financial support.

REFERENCES

Anon. (1980). M.A.F.F. Animal disease report. U.K. No. 2. 4-7.

Cook, B. R. (1965). The incidence and epidemiology of Echinococcus granulosus in Great Britain. Ph.D Thesis, University of Liverpool.

Cook, B. R. and Clarkson, M. J. (1971). The epidemiology of Echinococcus infection in Great Britain. III. Echinococcus granulosus and cestodes of the genus Taenia in farm dogs in England in the Lake District, northern Pennines and East Anglia. Annals of Trop. Med. and Parasitol. 65, 71-79.

Edwards, G. T., Hackett, F. and Herbert, I. V. (1979). Taenia hydatigena and Taenia multicips infections in Snowdonia, U.K. II. The role of hunting dogs and foxes as definitive hosts, and of sheep as intermediate hosts. Br. Vet. J. 135, 433-439.

Edwards, G. T. and Herbert, I. V. (1982). Observations on the course of Taenia multiceps infections in sheep: Clinical signs and post-mortem findings. Br. Vet. J. 138, 489-500.

Hackett, F. and Walters, T. M. H. (1980). Helminths of the red fox in mid-Wales. Vet. Parasitol. 7, 181-184.

Lawson, J. R. and Gemmel, M. A. (in press). Advances in Parasitology.

Stallbaumer, M. (1984). The survival of Taenia pisiformis eggs on pasture in England. Submitted to Vet. Parasitol.

Vicary, R. W. G. (1979). Coenurosis in sheep. Vet. Rec. 105, 21.

Williams, B. M. (1976a). The epidemiology of adult and larval(tissue) cestodes in Dyfed (U.K.) 1, The cestodes of farm dogs. Vet. Parasitol. 1, 271-276.

Williams, B. M. (1976c). The intestinal parasites of the red fox in south west Wales. Br. Vet. J. 132, 309-312.

COMPARATIVE STUDY OF GASTROINTESTINAL HELMINTHIASIS IN SHEEP ON 'CLEAN' GRAZING AND PERMANENT PASTURE UNDER FIELD CONDITIONS

G.B.B. MITCHELL*, J. FITZSIMONS**, A.O. MATHIESON***

An investigation of sources of helminth infection was carried out on three flocks: a traditional permanent pasture flock (A), one operating a 'clean' grazing system (B), and an East of Scotland College flock (C) which had operated a clean grazing system for nine years. Ewe and lamb worm egg output and pasture larval levels were recorded and tracer lambs were grazed during July and August on each farm. Considerable contamination was present on farm B fields compared with farms A and C, which resulted in higher worm burdens in late summer in farm B tracer lambs and lower weight gains. The main source of this infection was thought to be ewe periparturient egg output, as 21 per cent of ewes had positive worm egg counts over the lambing period. Differences in management practices between farms B and C, e.g. earlier stocking of farm B fields, were also considered contributory factors.

In the course of a previous study (Mitchell and Fitzsimons 1983) relatively high worm burdens were observed during late summer in commercial lambs on 'clean' pasture, i.e. young grass on which only dosed ewes had grazed the previous autumn. Such burdens were significantly greater than those acquired over the same period by lambs grazing permanent pasture or similar 'clean' grazing on an East of Scotland College farm. The reasons for this rather anomalous result were not apparent and the situation was further complicated by different dosing regimes employed on each farm, including the incorporation of a second ewe dose one month after the routine lambing dose.

In view of the demonstration of the benefits of 'clean' grazing both in terms of higher summer stocking rates and increased production by Rutter et al (1977), it was decided to repeat the comparison of worm burdens acquired by lambs on 'clean' grazing and permanent pasture. For the purposes of this comparison, Nematodirus species have been omitted.

Materials and methods

The experimental design is illustrated in Table 1. On farm A, 155 Scottish halfbred ewes with mainly twin Suffolk cross lambs were set-stocked, immediately after lambing, during March and early April, on two fields of permanent sheep pasture. Ewes were dosed seven to 10 days before lambing and lambs dosed on June 1, 1982. On farm B, 380 Scottish halfbred ewes with mainly twin Suffolk cross lambs divided into two groups were set-stocked, during late March, immediately following a post lambing ewe dose (two to five days after lambing) on two fields ploughed and reseeded in early autumn following a cereal crop. Dosed ewes had grazed these reseeded areas for six weeks at tupping time. On farm C (East of Scotland College farm), 180 Scottish halfbred ewes and mainly twin Suffolk cross lambs were moved from April 23 to 28, 1982, onto two young grass fields which had been grazed only by dosed ewes for six weeks the previous autumn. Ewes and any lambs

* G.B.B. Mitchell, Veterinary Investigation Centre, Auchincruive, Ayr
** J. Fitzsimons, East of Scotland College of Agriculture, West Mains Road, Edinburgh
*** A.O. Mathieson, Veterinary Investigation Centre, Bush Estate, Midlothian

over two weeks old were dosed immediately before being moved.

On both fields of farms A, B and C pasture larval counts were carried out fortnightly from April to October by a modification of the technique described by Taylor (1939). Ewe faecal egg counts were carried out fortnightly during April and May and lamb worm egg counts of individually identified lambs (30 to 40 per field) fortnightly from June to August by a modified McMaster technique. Lambs were weighed at the beginning of May and at weaning. Dosed tracer lambs were introduced to each field, then removed after one month and kept indoors for two weeks before slaughter in August and September respectively, when total worm counts were carried out on the contents of abomasa and small intestines by standard techniques.

Pasture larval counts in this paper refer only to Ostertagia circumcincta, the dominant species encountered, while worm egg counts and tracer lamb worm counts refer to strongyles.

Statistical analyses were carried out using Student's t test where variances were of a similar order, otherwise the Mann-Whitney U test was applied.

Table 1: Experimental design (1982)

Farm	Field	Ewes hectare^{-1}	Lambing commenced	Ewe treatment	Lamb treatment	Lambs weaned	Tracer lambs July	Tracer lambs August
A	1	9.9	March 22	Fenbendazole five to 10 days before lambing	Fenbendazole June 1	July 20	4	4
	2	9.9			Fenbendazole June 1	July 20	4	4
B	1	12.3	March 19	Fenbendazole two to five days after lambing	-	July 22	4	4
	2	12.3			-	July 21	4	4
C	1	14.8	March 18	Fenbendazole April 28	Fenbendazole if two weeks old April 23	August 8	4	4
	2	14.8		Fenbendazole April 23	Fenbendazole if two weeks old April 28	August 9	4	4

Results

The presence of overwintered larvae (less than 444 L3 kg^{-1}) was recorded on the permanent pasture fields of farm A in April (Fig 1) and lamb worm egg counts (less than 300 eggs per gram (epg)) in May. Larval counts on these fields then declined in May, rising again to peak at 3523 and 2073 L3 kg^{-1} respectively in July and August, coinciding with periods of rainfall. Lamb worm egg counts were low during June following dosing, rising again to fluctuate around 400 epg in July, before increasing sharply in late August to September to peak values more than 1000 epg.

On farms B and C ('clean' grazing) (Figs 2 and 3) overwintered larvae (peak values of 201 and 435 L3 kg^{-1} respectively) were recorded, which fell away before increasing from late June onwards to 2050 and 9434 L3 kg^{-1} on farm B fields and 330 and 475 L3 kg^{-1} on farm C fields. Thus farm C levels were of a similar order, but on farm B, the peak count on field 1 markedly exceeded that on field 2. The appearance of larvae on the pasture on farm B was followed by increasing lamb worm egg counts from June onwards to peak values of 1500 to 2000 epg in August to September. A much smaller rise in lamb egg counts occurred on farm C fields from late July to 300 to 400 epg. On both farms larval peaks correlated well with periods of rainfall.

Table 2: Ewe worm egg counts April to May 1982

Farm	Field	% Positive April	May	Range (epg)
A	1	50	50	100 to 500
	2	42	19	100 to 200
B	1	24	0	100 to 600
	2	16	50	100 to 400
C*	1	95	6	100 to 1200
	2	41	11	100 to 300

* Ewes dosed April 23 and 28

Considerable contamination of farm A and B fields was occurring from ewes during April and May after the lambing dose, presumably because of reinfection (Table 2). Farm C ewes also carried periparturient burdens, but were grazed on other pasture until late April, limiting contamination of farm C fields.

Mean liveweight gains to weaning were 14.6, 13.6 and 17.1 kg on farms A, B and C respectively. Farm C lambs had significantly greater weight gains than A or B ($P < 0.1$) while farm A lambs had significantly greater weight gains than farm B lambs ($P < 0.1$).

Group mean worm counts of tracer lambs on all three farms are illustrated in Table 3. O circumcincta was the dominant species, with fewer O trifurcata, Nematodirus battus, Trichostrongylus and Cooperia species. Variation in individual worm burdens within groups tended to be high. During July worm burdens were generally low (less than 4000) on all three farms and lambs from both fields on the same farm generally had similar worm burdens. In Table 4 tracer lambs have been considered together for each month, except for July tracers on farm C and August tracers on farm A which had significantly different burdens ($P < 0.01$). Farm B tracers during July had significantly greater worm burdens than any other group ($P < 0.01$) while farm A lambs had significantly greater burdens than one group of farm C lambs ($P < 0.025$). August worm burdens of all groups exceeded July burdens, and counts of 8300 and 4025 were recorded on farm A and 15,025 and 13,487 on farm B. Again farm B lambs had significantly greater burdens than other groups ($P < 0.01$), except farm A, field 1. Farm A burdens were greater than those on farm C ($P < 0.025$), which had relatively low burdens during both months.

Discussion

On the permanent pasture (farm A, Fig 1) larval counts and lamb egg counts showed a biphasic pattern despite anthelmintic treatment of ewes and lambs. Early activity of overwintered larvae produced a spring infection in the

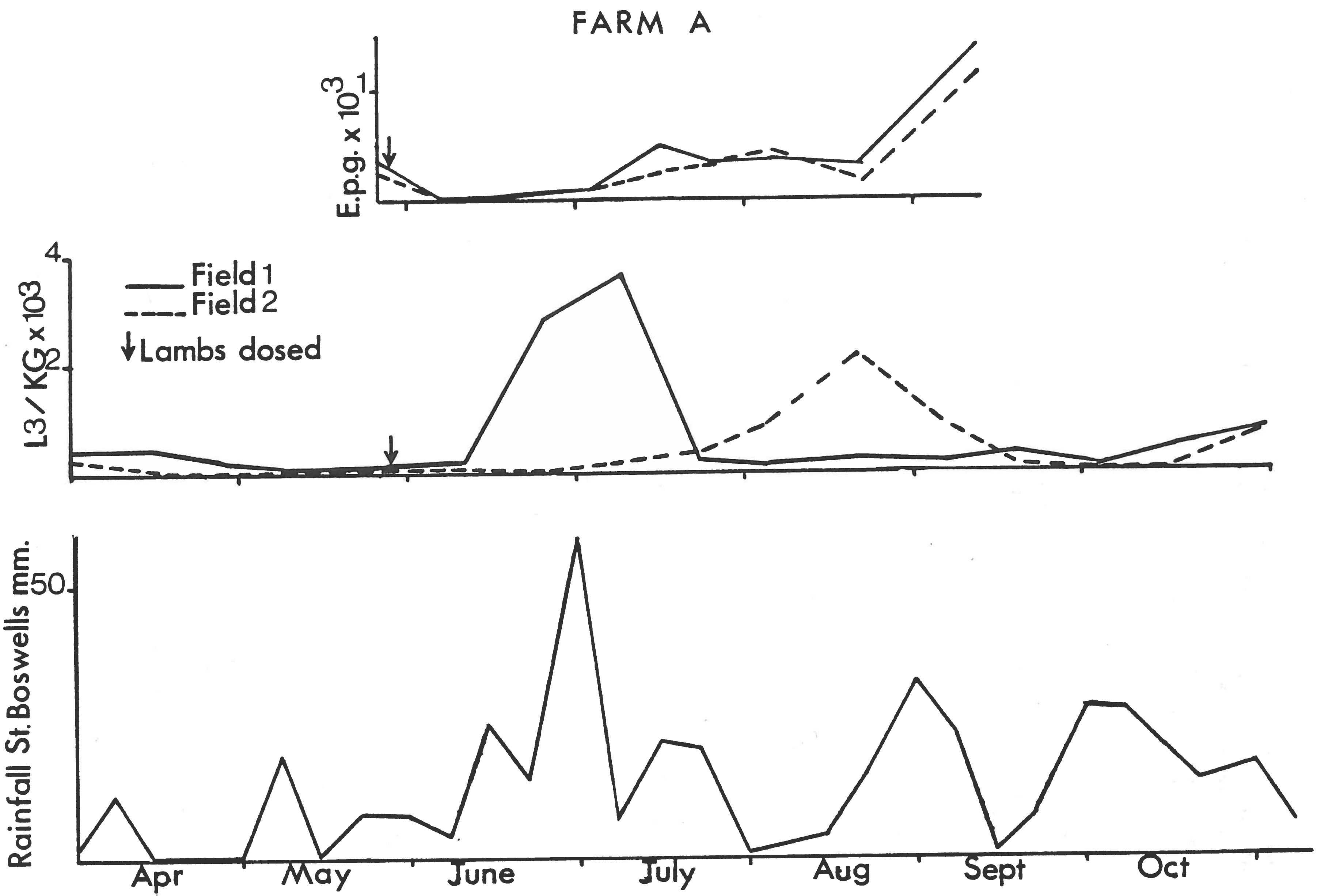


FIG 1: Lamb worm egg counts and pasture larval counts on farm A shown with rainfall during 1982.

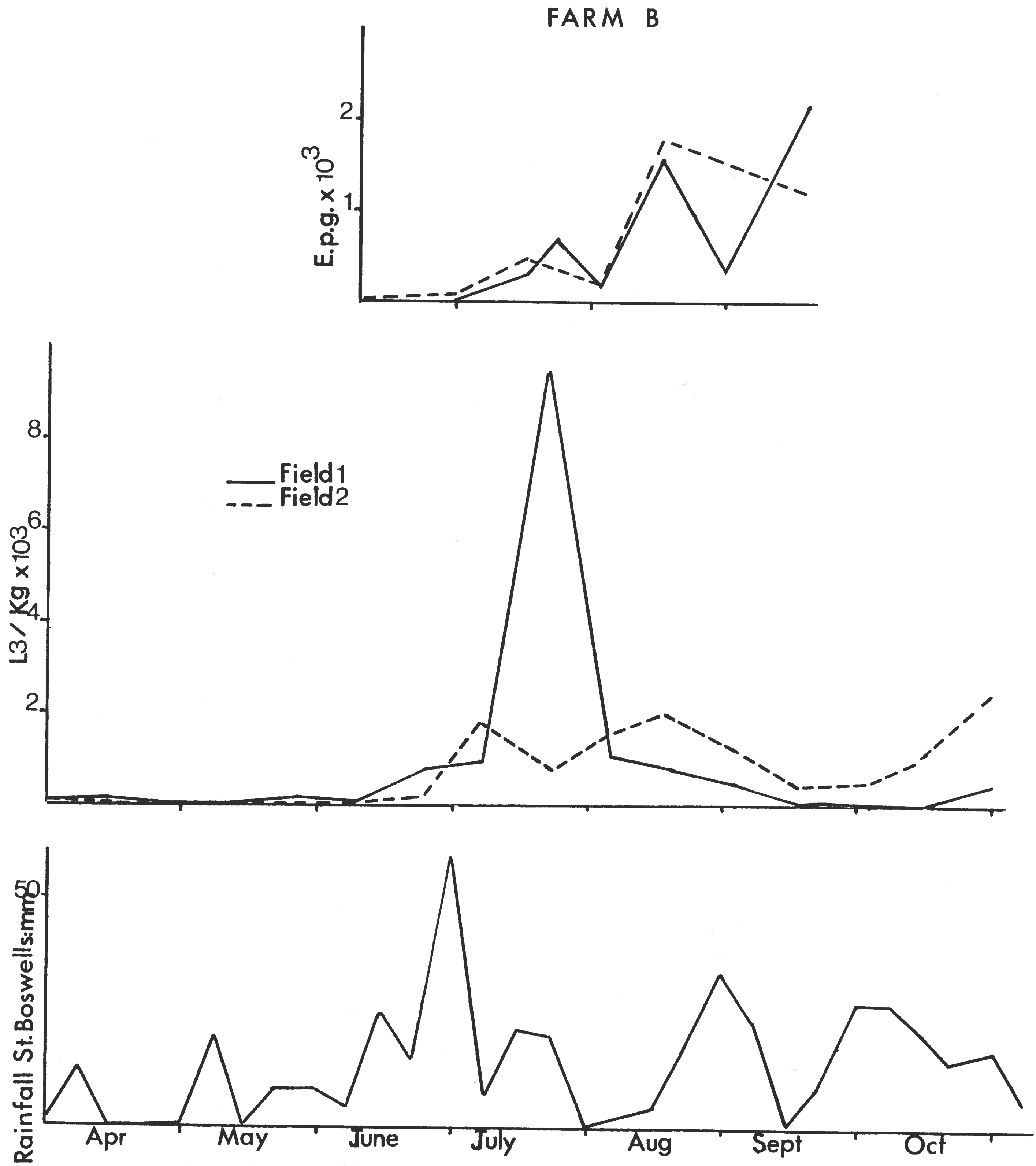


FIG 2: Lamb worm egg counts and pasture larval counts on farm B shown with rainfall during 1982.

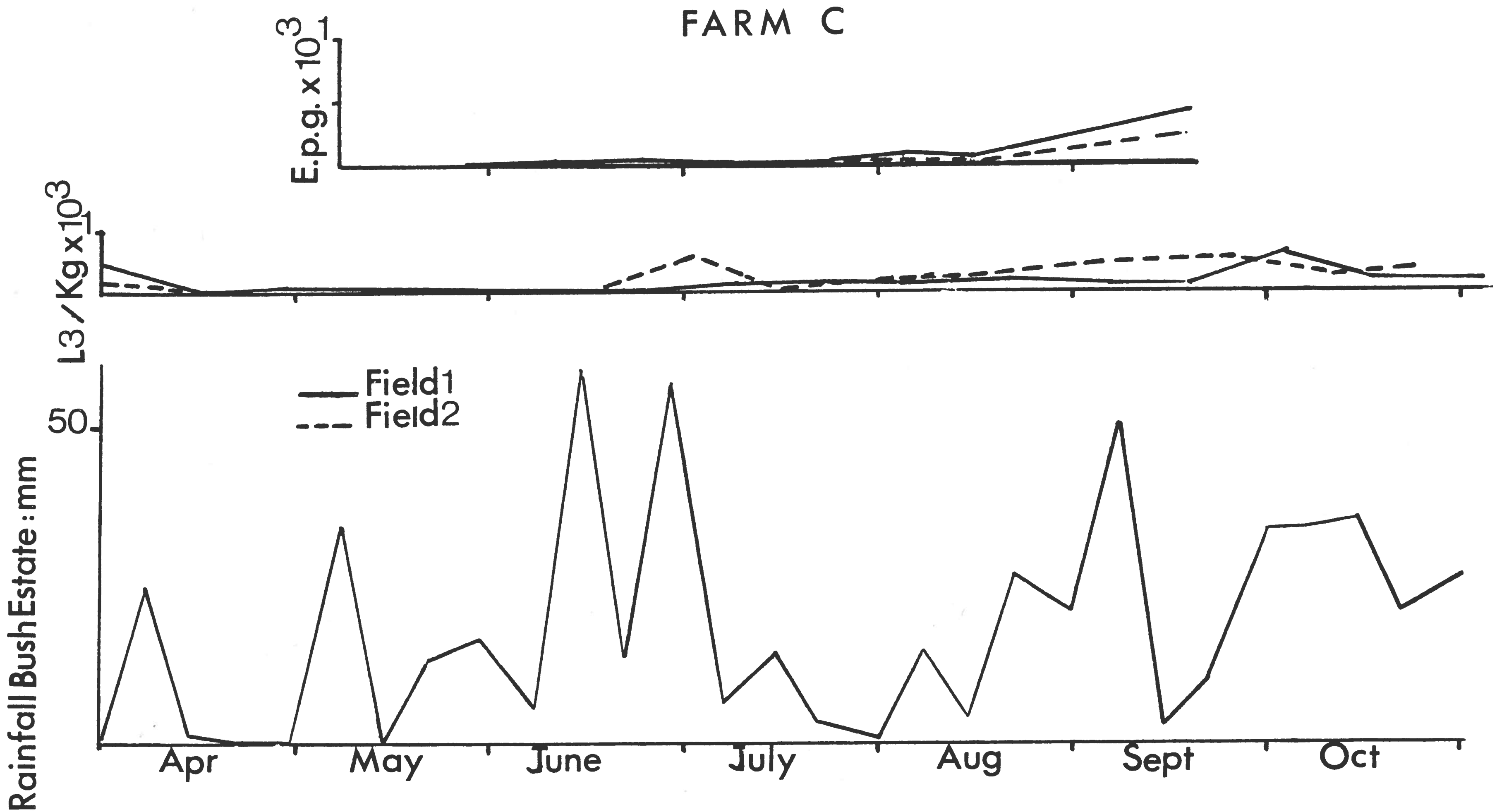


FIG 3: Lamb worm egg counts and pasture larval counts on farm C shown with rainfall during 1982.

lambs, terminated by dosing, which was followed by a much greater period of summer activity attributable to the development of eggs passed in spring by ewes and lambs.

On both 'clean' grazing farms (B and C), overwintered larvae were detected but did not result in significant egg counts in the lambs in spring. On farm B this may have been a quantitative effect since fields on farms A and B were stocked at the same time, i.e. immediately after lambing but fewer larvae were present on farm B fields. Residual contamination of farm C fields was comparable with farm A, but had largely died out by the time the fields were stocked (late April and early May).

A larval rise in late summer on both farms B and C did, however, result in lamb infection which was considerably greater in farm B lambs as measured by lamb worm egg counts and tracer lamb worm burdens. This wave of infection was probably caused primarily by larvae developing from eggs passed by ewes around lambing time and, although approximately one in four ewes on both farms was passing eggs over this period (Table 2), later stocking of farm C fields (late April) compared with farm B (late March) clearly reduced the numbers of larvae available for lambs from mid summer onwards. The contribution of lambs to the annual pasture larval rise by cycling over-wintered infection would have been similarly reduced on farm C.

These conclusions are in broad agreement with the findings of previous field (Mitchell and Fitzsimons 1983) and experimental studies on acquisition of helminth infections by sheep (Boag and Thomas 1971, Thomas and Boag 1972, Gibson and Everett 1973).

Table 3: Group mean worm counts in tracer lambs

Farm	A		B		C	
Field	1	2	1	2	1	2
July	800 $\pm$ 923	250 $\pm$ 234 NS	1950 $\pm$ 1228	3793 $\pm$ 3859 NS	212 $\pm$ 266	12 $\pm$ 25 P 0.025
August	8300 $\pm$ 2001	4025 $\pm$ 1410 P 0.01	15,025 $\pm$ 6761	13,487 $\pm$ 6639 NS	1962 $\pm$ 1401	1162 $\pm$ 756 NS

NS Not significant

Table 4: Statistical analysis of total worm counts in tracer lambs

Month	Farm		Farm	Significance
July	Farm B	>	Farm A	$P < 0.01$
	Farm B	>	Farm C (field 1)	$P < 0.01$
	Farm B	>	Farm C (field 2)	$P < 0.01$
	Farm A	>	Farm C (field 1)	NS
	Farm A	>	Farm C (field 2)	$P < 0.025$
August	Farm B	>	Farm A (field 1)	NS
	Farm B	>	Farm A (field 2)	$P < 0.01$
	Farm B	>	Farm C	$P < 0.01$
	Farm A (field 1)	>	Farm C	$P < 0.01$
	Farm A (field 2)	>	Farm C	$P < 0.025$

NS Not significant

Figs 1, 2 and 3 demonstrate obvious differences between the levels of contamination present on the three farms, farm B being comparable with farm A, presumably because of reinfection of farm B ewes after the lambing dose by overwintered larvae which were also present on farm C, but were not cycled due to later stocking. Thus it would appear that ewe grazing in autumn is potentially hazardous for the following year's lamb crop as this must have been the source of overwintered larvae, rendering pasture 'unclean' for lambs, and would suggest that young grass should not be grazed at all by sheep in the previous year. The results also suggest that, if possible, dosing and stocking of young grass fields should be delayed until late spring when grass growth has begun, thus reducing contamination for lambs later in the season.

Although marked differences were recorded in pasture larval levels between the two fields monitored on both farms A and B, this was not reflected in lamb egg counts. This emphasises the deficiencies of the pasture larval technique for quantitative assessment except where the differences are very large, as between farms A, B and C, although its usefulness lies in estimation of seasonal availability of infection.

Considerable variation between fields was evident in worm burdens of tracer lambs which correlated to some extent with differences in larval counts. During July and August, farm B tracer lambs had significantly greater burdens than tracers on both other farms with burdens of 15,025 and 13,487 being recorded in August which must have impaired lamb performance as shown by the studies of Coop and Angus (1981). Farm C lambs, in contrast, had significantly lower burdens than all other groups during both months, while farm A lambs occupied an intermediate position with August tracer burdens of 8300 and 4025, which again would have adversely affected lamb performance.

It should be noted that lamb performance in terms of liveweight gain to weaning was greatest on farm C and poorest on farm B with farm A occupying the middle position, despite the higher stocking rate (14.8 hectare^{-1}) on farm C, although without taking account of other variable factors such a comparison must be made cautiously.

Whitelaw and Fawcett (1982) suggested that lambs reared on 'clean' pasture do not develop a significant level of acquired immunity to helminth infection, and when challenged by appreciable numbers of infective larvae for the first time will develop higher worm burdens than lambs which have been previously exposed to infection, having been reared on permanent pasture. In the present and previous studies (Mitchell and Fitzsimons 1983) commercial lambs reared on new ley pasture acquired larger worm burdens than lambs on permanent pasture. Although this was largely attributable to the degree of pasture contamination by the ewes, the possibility of a lack of acquired immunity in the lambs on young grass may be an additional factor, since lambs on permanent pasture had received a priming infection in spring. Further studies including similar field challenge of lambs reared under both systems are required to investigate this proposition.

Recent work on the persistence of helminth larvae in soil on cattle (Bairden et al 1979 , Al Saqur et al 1982) and sheep (Gruner et al 1980) pastures has demonstrated the importance of this reservoir of infection, which was not investigated in the present studies.

The apparent failure of 'clean' grazing on farm B was clearly due to the fact that the pasture was not really clean, because of residual contamination from autumn ewe grazing. The effectiveness of the system operated on farm C may well have owed more to later stocking, enabling ewes and lambs to evade reinfection than control of overwintering. The evidence of the present series of studies carried out over a three year period indicates that avoidance of autumn grazing is necessary to produce clean spring pasture.

References

Al Saqur, I., Bairden, K., Armour, J. & Gettinby, G. (1982). Research in Veterinary Science 32, 332-337.

Bairden, K., Parkins, J.J. & Armour, J. (1979). Veterinary Record 106, 332-337.

Boag, B. & Thomas, R.J. (1971). Research in Veterinary Science 12, 132-139.

Coop, R.L. & Angus, K.W. (1981). Veterinary Record Supplement, In Practice 3, number 4, 4-11.

Gibson, T.E. & Everett, G. (1973) British Veterinary Journal 129, 448-455.

Gruner. L., Mauleon, H., Hubert, J. & Sauve, C. (1980). Annales de Recherches Vétérinaire 11, 133-140.

Mitchell, G.B.B. & Fitzsimons, J. (1983). Research in Veterinary Science 5, 100-105.

Rutter, W., Black, W.J.M., Carson, I.S., Fitzsimons, J. & Swift, G. (1977). Proceedings of the European Association for Animal Production. 28th Annual Meeting, Brussels. pp 1-5.

Taylor, E.L. (1939). Journal of Helminthology 31, 473-478.

Thomas, R.J. & Boag, B. (1972). Research in Veterinary Science 13, 61-69.

Whitelaw, A. & Fawcett, A.R. (1982). Veterinary Record 111, 224-225.

THE EPIDEMIOLOGY OF OVINE TOXOPLASMOSIS

M. J. CLARKSON*, W. B. FAULL*, N. TADICH*& A. WINTER*

Abortion is an increasingly important disease problem in British sheep and toxoplasmosis accounts for about a third of all diagnosed abortion incidents, according to the Ministry of Agriculture VIDA figures.

Toxoplasma is a ubiquitous parasite in that tissue cysts and antibody have been discovered in a wide range of host species but the life cycle is only completed in the cat, in which the parasite behaves as a typical coccidian, giving rise to Isospora-like oocysts.

Blewett (1983) and Blewett and Watson (1983, 1984) have discussed the epidemiology of ovine toxoplasmosis and postulated models of infection to explain the published serological data and the clinical manifestations of the disease in sheep flocks.

Blewett and Watson (1984) discussed the possible mechanisms of transmission and conclude that the majority of outbreaks can be best explained by the discontinuous exposure of pregnant ewes to cat oocysts. They stressed the fact that the precise circumstances under which sheep are actually exposed to these oocysts by the ingestion of cat faeces is largely unknown, though one well-attested case where feedstuff became contaminated with cat faeces has been described in Australia (Plant, Richardson & Moyle, 1974).

We were invited to produce a health programme on a sheep farm in 1981 in which the farmer indicated that his problems included a small number of barren ewes and some abortions due to Toxoplasma. It became apparent that these were recurring annual problems. A study of the lambing performance was made in 1982 and this led to a more detailed study of the acquisition of Toxoplasma infection in 1983 and 1984.

The farmer purchased some 250-300 ewe-lambs in September each year at a Welsh half-bred sale, though he knew the farms of origin and tended to purchase the lambs from the same half-dozen or so farms each year. The lambs were put to the tup in November for prime lamb production and a proportion of the ewes were sold after one year on the farm, the remainder being tupped a second time. All the remaining ewes were sold after two years on the farm. The flock thus consisted of two age groups only. The ewes lambing in the first season had a poor fertility and the Toxoplasma abortions occurred amongst them whereas the ewes in their second year had a high fertility and no Toxoplasma abortions. Serology revealed that the second year ewes had high titres to Toxoplasma.

In September 1982, all the replacement lambs (almost 300) were individually tagged and bled for Toxoplasma antibody the day after arrival on the farm and only two were sero-positive. One hundred ewe lambs were bled in December, February and April and their sera tested for Toxoplasma antibody. These studies showed that a rapid rate of sero-conversion was occurring and that the majority of

*University of Liverpool, Department of Veterinary Clinical Science, Division of Farm Animal Medicine, Veterinary Field Station, 'Leahurst', Chester High Road, Neston, South Wirral, L64 7TE.

lambs had been exposed to infection whilst grazing and before any supplementary feed (hay, silage or concentrate) had been fed. The rate of acquisition of infection, as judged by sero-conversion, fitted the epidemic model suggested by Blewett (1983).

A theory was proposed that bedding in the sheep house became contaminated with cat faeces during the winter housing period (January to April) and that this contaminated bedding, which was spread on the pastures in the summer, acted as the source of infection for the replacement lambs in the following autumn and winter.

In 1983/84 a trial was conducted in which one group of ewe-lambs was maintained from arrival on pasture which had not been spread with sheep bedding ('clean') and their rate of sero-conversion was compared with that of a group of ewes grazing on pasture on which the bedding had been spread ('dirty'). With the exception of a small group of ewe-lambs which were either sero-positive on arrival or became sero-positive soon after, all of which originated from a single farm, none of the ewes grazing the 'clean' pasture had sero-converted by December whereas over 30% of the ewes grazing the dirty pasture had done so, a similar figure to the previous year. (A possible explanation for the small group of ewes which were sero-positive on arrival was obtained by a visit to the farm of origin by our colleague, Dr. A. J. Trees.)

The two groups of ewes were combined in late November and a high proportion of both groups had sero-converted by April. Possible explanations for this will be discussed and the relationship between the time of acquisition of Toxoplasma infection and lambing performance will be described.

The models described by Blewett (1983) and Blewett and Watson (1983, 1984) will be used to attempt to explain the findings and to indicate possible methods of control of toxoplasmosis on this farm.

REFERENCES

Blewett, D. A. (1983). The epidemiology of ovine toxoplasmosis. I. The interpretation of data for the prevalence of antibody in sheep and other host species. Br. Vet. J. 139, 537-545.

Blewett, D. A. and Watson, W. A. (1983). The epidemiology of ovine toxoplasmosis. II. Possible sources of infection in outbreaks of clinical disease. Br. Vet. J. 139, 546-555.

Blewett, D. A. and Watson, W. A. (1984). The epidemiology of ovine toxoplasmosis. III. Observations on outbreaks of clinical toxoplasmosis in relation to possible mechanisms of transmission. Br. Vet. J. 140, 54-63.

Plant, J. W., Richardson, N. and Moyle, G. G. (1974). Toxplasma infection and abortion in sheep associated with feeding of grain contaminated with cat faeces. Aust.Vet. J. 50, 19-21.

STAPHYLOCOCCAL FOLLICULITIS IN SUCKING LAMBS

G.R. SCOTT, J.B. LAWSON, A.H. LAING, E.A. McPHERSON
and J.S.D. RITCHIE*

From time immemorial, Scottish shepherds and flockmasters have been familiar with "plookie lammies", a trivial affliction that rarely, if ever, comes to the attention of the practising veterinarian. It is not unknown south of the border; Parker and his colleagues, for example, reported the presence of a similar condition in the unweaned lambs of an experimental flock at the Central Veterinary Laboratory, Weybridge in 1983. Our interest arose serendipitously in the course of a long-term investigation of the annual prevalence of orf in two flocks of sheep on the Easter Bush farm of the University of Edinburgh Veterinary Field Station. Every lamb in the last 19 years has been examined clinically every one to two weeks until sold fat or drafted into the ewe-hogg flock as a stock replacement. Small pustules that rapidly became encrusted were often observed around the lips, muzzles and nostrils. They were readily differentiated from orf lesions when the scab was removed; a pit indicated a pustule; and a granuloma an orf lesion. It slowly dawned on us that the frequency with which we saw non-orf pustules was high and that, moreover, their occurrence seemed to follow a regular pattern. For eight years, thereafter, detailed records of the incidence of the facial pustular lesions were kept and analysed. The conclusions are herein presented. In addition, the aetiology and histopathology of the condition were investigated.

MATERIALS AND METHODS

Easter Bush farm

Easter Bush is a mixed stock farm with a high stocking density of grazing animals on the outskirts of Edinburgh. Although the farm lies at an altitude of 190 metres there is no rough grazing, all 80 hectares being rotationally cultivated. The district is tick-free.

January flock

The sheep in the January flock were pedigreed Suffolks that were lambed indoors in January. The ewes and lambs were only turned out to grass in late March or early April. Lambs were routinely weaned when 12 weeks old but on three occasions small numbers of lambs were weaned at birth, dried and reared artificially. The numbers of ewes and lambs in the January flock in the relevant years fluctuated between 24 and 44 and between 37 to 66 respectively. The cumulative total of January lambs studied was 394.

*University of Edinburgh Veterinary Field Station, Easter Bush, Roslin, Midlothian EH25 9RG.

April flock

The April flock is a typical lowground commercial flock producing cross-bred lambs outdoors on grass in April and early May. On one occasion only a few April lambs were weaned at birth and reared artificially. The numbers of ewes and lambs in the April flock in the relevant years ranged from 31 to 118 and from 35 to 194 respectively. The April lambs totalled 1098.

Clinical examinations

Every week for ten weeks after birth every lamb was handled and its head examined closely for pustules and orf lesions. Thereafter healthy lambs were examined fortnightly. If orf, however, was present in the flock the clinical monitoring of all lambs continued at weekly intervals. On three occasions, lambs were also searched for pustular lesions in the skin of the perineum and ventral cauda. Each lamb had its own number and records of its health status were maintained throughout the period of observations.

Clinicians wore disposable gloves. These were discarded whenever a case of orf was detected but gloves were not changed when pustules were encountered.

Collection of diagnostic specimens

Throughout one series of weekly observations every new case of pustular dermatitis was sampled by swabbing the lesions, later, pustules were swabbed only intermittently to confirm the presence and nature of the causative organisms. In addition, several biopsies of the pustules and immediately adjacent tissues were made using disposable 3 mm trephines. These samples were fixed immediately by immersion in buffered 10 percent formal-saline.

Scabs were collected from all the suspect index cases of orf. On occasion, biopsies of the underlying granulomas were also collected.

Examination of diagnostic specimens

Pustule contents were plated onto 5 percent ox or sheep blood agar and incubated at 37°C for 24 hours. The characteristics of any bacterial colonies and the types of haemolytic activity were noted. Smears from single colonies were stained with Gram and examined for cocci. A tube-test with fresh rabbit plasma was used to assess coagulase production by Gram-positive cocci (Cowan, 1974).

Biopsies of pustular lesions were left in formal-saline for 48 hours and then dehydrated through a series of alcohols into xylol before embedding in paraffin wax. Sections, approximately 5 microns thick, were cut, floated off and trapped on microscope slides to dry. Sections, thereafter, were stained with haemotoxylin and eosin.

Scabs from suspect cases of orf were broken up into 2 mm cubes which, in turn, were teased out in a drop of distilled water. Coated copper-mesh grids were floated on the drops for 30 seconds before being stained negatively by being floated on a drop of 2 percent phosphotungstate acid for 30 seconds. Biopsies of suspected-orf granulomas were fixed in 3 percent gluteraldehyde in one percent cacodylate buffer, post-fixed in one percent osmium tetroxide, dehydrated and embedded in araldite resin. Ultrathin sections were mounted on copper-mesh grids and negatively stained. Grids were examined at a magnification of x30,000 in an electron microscope.

RESULTS

Clinical signs

There was no systemic disturbance. The pyodermatitis was manifested by the emergence of bulging pustules, 2-5 mm in diameter and ringed with erythema. The pustules occurred either singly or in a crop in the skin around the lips, muzzle and nostrils or in the skin of the perineum and under the tail. Occasionally both sites were attacked simultaneously. The facial lesions encrusted more rapidly than the perineal lesions. The lesions healed without scar formation but the site of the healed lesion was conspicuous for some time as an irregularly shaped, smooth, white patch if the skin was pigmented. Fresh crops of pustules sometimes occurred.

Pathology

Gross pathological changes were limited to the affected sites. Histopathologically, the lesion was a pyogenic folliculitis underlying an inflamed, ulcerated epidermis. Sebaceous glands were not involved.

Aetiology

Bacteria were isolated from pustular lesions in 59 of 63 new cases of pyogenic folliculitis. Fifteen samples yielded mixed cultures, eight of which included coagulase positive beta-haemolytic staphylococci. In addition, samples from 40 lambs yielded heavy pure growths of coagulase-positive beta-haemolytic staphylococci. Alpha-haemolytic streptococci were recovered from 4 samples, one of which also contained coagulase-positive staphylococci. Two other mixed cultures yielded centhracoid and in one mixed culture *Dermatophilus congolensis* was detected. In short, the most frequently isolated organisms were coagulase-positive, beta-haemolytic staphylococci. Subsequent sporadic isolations in the following years supported the hypothesis that they were the primary aetiological agent.

Incidence of facial pustules

Facial pustules first appeared on average in both flocks at the same time after the onset of lambing, namely at 2.6 ± 0.9 weeks and 2.6 ± 0.5 weeks in the January and April flocks respectively. Both incidence curves were positively skewed (Tables 1 and 2). The incidences peaked in the January flock 7.4 ± 1.8 weeks after the onset of lambing and in the April flock at 5.2 ± 0.9 weeks. Although this difference is significant ($t_{(7)} = 3.039$, $P < 0.02$) the peak incidences in the pooled data occurred in both flocks at 5 weeks after the onset of lambing, 2 weeks after the peak recruitments to the flocks (Table 3).

The durations of the epidemics in the indoor January flock averaged 10.1 ± 1.4 weeks, a period shorter than the 12.4 ± 3.2 weeks in the outdoor April flock; the difference, however was not significant ($t_{(7)} = 1.829$, $P > 0.10$). The durations of the epidemics were not correlated with the number of lambs at risk nor with the number affected.

Table 1. Incidence of facial pustules in the January flock

Week*	1968	1969	1970	1971	1972	1973	1974	1975
1	0	0	3	0	0	0	0	0
2	0	0	1	0	0	0	1	0
3	4	1	2	2	4	2	1	1
4	8	3	3	3	0	4	6	2
5	12	6	3	1	3	4	13	1
6	6	5	3	4	4	1	7	1
7	5	7	3	8	1	2	5	2
8	2	3	5	5	6	4	0	2
9	4	1	4	1	2	3	1	3
10	1	3	1	3	1	5	1	2
11	1	3	0	2	2	4	0	2
12	0	1	0	0	2	1	1	0
13	0	0	0	0	1	0	0	0
14	0	0	0	0	2	0	0	0
15	0	0	0	0	1	0	0	0
Totals	43	33	28	29	29	30	36	16

*after onset of lambing

Table 2. Incidence of facial pustules in the April flock

Week*	1968	1969	1970	1971	1972	1973	1974	1975
1	0	0	0	0	0	0	0	0
2	0	0	0	1	0	0	1	3
3	3	3	2	1	2	1	1	5
4	2	4	1	8	6	12	1	12
5	3	5	7	11	16	17	5	8
6	2	3	15	8	12	6	5	4
7	2	6	15	10	17	12	3	1
8	1	5	13	5	12	8	3	1
9	1	7	5	2	12	6	0	3
10	0	2	0	2	10	3	0	2
11	0	4	1	7	1	1	4	0
12	0	6	1	3	3	2	3	0
13	0	7	0	3	1	2	0	1
14	0	7	0	2	4	1	0	2
15	0	2	0	0	0	1	0	1
16	0	1	0	0	0	1	0	0
17	0	2	0	0	0	1	0	0
18	0	3	0	0	0	2	0	0
19	0	0	0	0	0	1	0	0
Totals	14	67	60	63	96	27	26	43

*after onset of lambing

Table 3. Pooled number of lamb recruits and pooled incidence of facial pustules

Week*	January flock		April flock	
	Recruits	Incidence	Recruits	Incidence
1	56	3	101	0
2	100	2	208	5
3	113	17	340	18
4	53	29	141	46
5	46	43	171	72
6	11	31	59	55
7	11	33	25	66
8	0	27	26	48
9	4	19	14	36
10	0	17	0	19
11	0	14	7	18
12	0	5	0	18
13	0	1	6	14
14	0	2	0	16
15	0	1	0	4
16	0	0	0	2
17	0	0	0	3
18	0	0	0	5
19	0	0	0	1
Totals	394	244	1098	446

*after onset of lambing

Prevalence of facial pustules

Pustules were noted every year in sucking lambs, the annual prevalence in the indoor January flock ranging from 39 to 88 percent and in the outdoor April flock from 15 to 70 percent (Table 4). The data were symmetrical, the means and standard deviations being 63 ± 17 and 43 ± 18 respectively.

Table 4. Annual prevalence (%) of facial pustular folliculitis in sucking lambs

Year	January flock	April flock
1968	88	35
1969	78	70
1970	65	58
1971	76	49
1972	56	54
1973	45	43
1974	56	15
1975	39	22

The differences in the annual prevalences of the two flocks were significant (Paired $t_{(7)} = 2.910^{*}$, $P < 0.05$). Similarly, the pooled prevalence rates of 62 and 11 percent in the January and April flocks differed significantly ($\chi^2 = 52.966^{**}$, $P < 0.001$) (Table 5).

Table 5. Cumulated totals of lambs at risk and cumulated cases of facial pustules

Week*	January flock		April flock	
	At risk	Cases	At risk	Cases
1	56	3	101	0
2	156	5	309	5
3	269	22	649	23
4	322	51	790	69
5	368	94	961	141
6	379	125	1020	196
7	390	158	1045	262
8	390	185	1071	310
9	394	204	1085	346
10	"	221	1085	365
11	"	235	1092	383
12	"	240	1092	401
13	"	241	1098	415
14	"	243	1098	431
15	"	244	"	435
16			"	437
17			"	440
18			"	445
19			"	446
Prevalence	0.62		0.41	

*after onset of lambing

The median births in both flocks occurred 3 weeks after the onset of lambing. The median cases occurred 6.8 ± 1.3 and 7.0 ± 1.6 weeks after the onset of lambing in the January and April flocks respectively; the difference was negligible ($t_{(14)} = 0.344$, $P > 0.99$).

Prevalence of orf

In contrast to the frequency with which pustular folliculitis was observed orf was only detected and confirmed by visualization of the characteristic ultrastructure of the virus particle in samples collected from January lambs in 5 out of the 8 relevant years and in samples from the April flock in 4 out of the 8 years. When both conditions occurred the median onset of the folliculitis always preceded the median onset of orf. McNemar's test of correlated proportions (1969) revealed that the distribution of orf among the lambs was not related to the distribution of the folliculitis either in the January flock ($\chi^2 = 55.309^{**}$, $P < 0.001$) or in the April flock ($\chi^2 = 91.524^{**}$, $P < 0.001$) (Tables 6 & 7).

Table 6. Distribution of facial folliculitis and orf in the January lambs

Year	Number at risk	Both present	Both absent	Folliculitis only	Orf only
1968	49	22	6	21	0
1969	42	16	6	17	3
1970	43	8	11	20	4
1971	37	8	3	21	5
1975	41	4	21	12	4
Totals	212	58	47	91	16

Table 7. Distribution of facial folliculitis and orf in the April lambs

Year	Number at risk	Both present	Both absent	Folliculitis only	Orf only
1968	40	8	25	6	1
1969	96	38	18	29	11
1970	103	8	40	52	3
1971	128	5	58	58	7
Totals	367	59	141	145	22

Facial pustules in early weaned lambs

Although lambs were always free of pustules at birth, we noted pustules in 3 out of the 690 affected lambs 24 hours after birth. Four small trials were set up to compare the prevalence of facial pustules in lambs weaned at birth and isolated thereafter from the flock with that in unweaned lambs left running with their ewes. It was lower in the weaned lambs but not significantly lower (χ^2 = 1.520, P > 0.05) (Table 8).

Table 8. Facial pustules in early weaned and unweaned lambs

Year	Weaned lambs		Unweaned lambs	
	At risk	Affected	At risk	Affected
1969	10	8	32	25
1971	21	6	107	57
1972	12	5	40	24
1973	12	6	54	24
Totals	55	25	233	130

Perineal pustules

When injecting an experimental orf vaccine into the tail-root we discovered a second common site of staphylococcal folliculitis, namely, the hairless and wool-free skin of the perineum and ventral cauda. Lambs in one indoor January flock and two outdoor April flocks were therefore monitored carefully for pustules at both sites (Tables 9 & 10). To validate comparisons between the responses of lambs in January and April a further trial was carried out with the 1981 January flock.

Table 9. Facial and perineal pustules in two January flocks

Week*	41 lambs in 1975			47 lambs in 1981		
	Facial pustules	Perineal pustules	Pustules at both sites	Facial pustules	Perineal pustules	Pustules at both sites
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	1	0	2	0
4	0	1	2	2	2	0
5	1	1	0	2	1	1
6	1	1	0	2	3	0
7	2	2	0	1	0	1
8	2	0	0	0	0	1
9	3	1	0	0	0	0
10	2	1	0	2	1	0
11	2	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
Totals	13	8	3	9	9	3

*after onset of lambing

Table 10. Facial and perineal pustules in two April flocks

Week*	178 lambs in 1974			194 lambs in 1975		
	Facial pustules	Perineal pustules	Pustules at both sites	Facial pustules	Perineal pustules	Pustules at both sites
1	0	0	0	0	0	0
2	0	2	1	3	4	0
3	1	4	0	3	6	2
4	0	8	1	9	7	3
5	4	6	1	6	5	2
6	4	6	1	2	4	2
7	3	4	0	1	4	0
8	2	3	1	0	4	1
9	0	0	0	3	0	0
10	0	0	0	2	0	0
11	4	0	0	0	2	0
12	3	0	0	0	1	0
13	0	0	0	1	1	0
14	0	0	0	2	0	0
15	0	0	0	1	0	0
Totals	21	33	5	33	38	10

*after onset of lambing

The clinical appearance, evolution, and course of the perineal lesions closely resembled that of the facial pustules. Thus perineal pustules first appeared in both flocks 2 weeks after the onset of lambing as compared to the 2.6 weeks of the facial pustules. The incidence of the perineal pustules in the January flocks peaked 6.5 weeks and in the April flocks at 4.0 weeks whereas the incidences of the facial pustules peaked at 7.5 and 5.2 weeks respectively in January and April flocks. The annual prevalences of perineal pustules were similar in both flocks, the overall prevalence being 24 percent ($\chi^2_{(3)}$ = 0.970, P > 0.80). This prevalence was similar to 21 percent of the facial pustules in lambs in the same flocks (χ^2 = 0.901, P > 0.30) but it was significantly smaller than the overall prevalence of facial pustules of 46 percent in all flocks (χ^2 = 73.954**, P < 0.001). Median cases occurred significantly earlier in the perineal syndrome, the mean weeks of occurrence after the onset of lambing being 5.2 and 6.9 in epidemics of perineal and facial pustules respectively ($t_{(18)}$ = 2.268*, P < 0.05). On the other hand, the durations of the epidemics of perineal and facial pustules were similar, namely 10.1 and 10.2 weeks respectively.

The unexpected feature was the low prevalence of pustules at both sites in the same lambs which ranged from 3 to 10 percent. Differences between flocks were not significant ($\chi^2_{(3)}$ = 2.482, P > 0.25).

Sex-related prevalence

In the January flocks 129 of the 244 lambs with facial pustules were female, a sex-related prevalence of 53 percent that was similar to the 46 percent of females among the 446 affected lambs in the April flocks (χ^2 = 3.011 P > 0.05). The pooled prevalence of 48 percent did not differ significantly from the 53 percent of female lambs that were not affected (χ^2 = 3.471, P > 0.05).

The prevalence of perineal pustules in female lambs overall was 68 percent, a prevalence significantly higher than the 50 percent prevalence of facial pustules in female lambs in the same flocks ($\chi^2_{(2)}$ = 7.830*, P < 0.02) (Table 11). No differences were attributable to the flock (χ^2 = 0.851, P > 0.30).

Table 11. Distribution of pustules by sex

Flock	All affected lambs	Face		Perineum		Both sites	
		male	female	male	female	male	female
April 1974	59	11	10	10	23	1	4
January 1975	24	6	7	4	4	1	2
April 1975	81	16	17	11	27	3	7
January 1981	21	5	4	3	6	0	3
Totals	185	38	38	28	60	5	16

Age-related prevalence

Two-way analyses of variances were used to assess differences in the ages of lambs when first afflicted. No differences attributable to flocks, years of occurrence or interactions were detected in either facial folliculitis or perineal folliculitis (Table 12).

Table 12. Significance of differences in the ages when lambs were infected

Source of variation	Facial pustules	Perineal pustules
Between flocks	$F^{1}_{674} = 2.71$	$F^{1}_{105} = 0.00$
Between years	$F^{7}_{674} = 1.47$	$F^{1}_{105} = 0.95$
Interaction	$F^{7}_{674} = 1.49$	$F^{1}_{105} = 0.06$

The overall means and standard deviations of the ages of lambs first afflicted with facial and perineal pustules were 4.2 ± 2.5 weeks and 3.3 ± 7.3 weeks respectively. The difference was highly significant ($t_{(797)}$ = 3.529**, $P < 0.01$).

Duration of the disease

The facial and perineal lesions healed in 2.1 ± 1.4 weeks and 2.3 ± 1.9 weeks respectively, a difference that was not significant ($t_{(797)}$ = 1.473, $P > 0.10$). Similarly there were no differences attributable to flocks or years.

Re-infection

Lesions recurred at both sites in both flocks every year. Most re-infections occurred once. Nevertheless 16 lambs were seen to be re-infected twice and four lambs thrice. Although re-infection rates between sites were similar (Table 13) the rates in the indoor January lambs were significantly higher at both sites than those in the outdoor April lambs (Table 14).

Table 13. Comparison of re-infection rates in lambs with facial and perineal pustules

Pustule site	Primary infection	Re-infection	Rate (%)	χ^2	P
Face	690	157	23	2.143	>0.100
Perineum	109	18	16		

Table 14. Comparison of re-infection rates in lambs of the January and April flocks

	Flock	Primary infection	Re-infection	Rate (%)	χ^2	P
Facial pustules:-	January	244	77	32	16.646**	<0.001
	April	446	80	18		
Perineal pustules:-	January	23	8	35	7.056**	<0.010
	April	86	10	12		

Lambs infected at one site tended to be re-infected at the same site (Table 15).

Table 15. Staphylococcal folliculitis: sites of re-infections

Primary site	Re-infection site	Number re-infected	%
Face	Face	8	31
Face	Perineum	2	8
Perineum	Perineum	8	31
Perineum	Face	3	12
Both sites	Face	5	19

The periods between primary and secondary infections of facial and perineal pustules in both flocks were similar, the overall average being 2.8 ± 1.8 weeks (Table 16).

Table 16. Significance of differences in periods between infection and re-infection with staphylococcal pustules

Source of variation	Degrees of freedom	Mean square	Variance ratio	P
Between flocks	1	7.7209	2.28	>0.50
Between sites	1	1.3530	0.40	>0.50
Interaction	1	8.9688	2.65	>0.50

The duration of the re-infections, however, was very significantly shorter than the duration of the primary infections averaging 1.4 ± 0.7 weeks as against 2.1 ± 1.4 weeks ($t_{(845)}$ = 6.024**, $P < 0.001$).

DISCUSSION

Staphylococcal folliculitis is a transient and trivial affliction of young lambs manifested by two remarkably concise syndromes that rarely occur together. One syndrome involves the skin of the perilabial and perinasal areas of the head and the other the skin of the perineum and ventral cauda. The essential clinical and epidemiological features of both syndromes differ only in minor ways. For example, the annual prevalence of facial pustules was the greater. Nevertheless perineal pustules appeared earlier after the onset of lambing, involved younger lambs and affected females more often than males. Minor differences are attributable also to husbandry practices; housed lambs had a higher annual prevalence of pustules than lambs born and reared outdoors. The peak incidence of folliculitis in indoor lambs, however, was later. Re-infections, moreover, occurred more often in indoor lambs. Lesions resolved faster in re-infections.

The plots of the incidence curves for each year have the typical positively skewed pattern of a virgin-soil epidemic, a finding that suggests that there is no passively acquired immunity to the causative staphylococci. The faster healing of the lesions in re-infections, however, points to some active stimulation of the immune defences, albeit low-grade.

The source of the staphylococci was not known. The organisms, however, are ubiquitous in flocks of sheep being harboured most often in noses and mouths of ewes before parturition and on the skin and in the vagina after parturition (Watson, 1965). Newborn lambs, therefore, are at risk from, or even at, birth.

The coagulase-positive beta-haemolytic staphylococcus causing the folliculitis is less pathogenic than the similar organism that induces the distressing facial and limb pyoderma known as staphylococcal dermatitis that has emerged recently as a problem in Europe (Scott et al., 1980). The two conditions are readily separable by the age distribution of the affected sheep, by the severity and character of the lesions, and by histopathology (Fraser et al., 1982). Staphylococcal dermatitis attacks all ages producing deep suppurative ulcers ringed by alopecia and capped with black scabs. The lesions heal slowly over a period of five to six weeks. Forceable removal of the scab exposes a deep crater with lytic contents. Staphylococcal folliculitis, on the other hand, is frequently mistaken for orf. Removal of the scab, however, will reveal a pustule pit instead of a bleeding orf granuloma. Because orf virus is known to require a break in the integument before it can initiate infection we expected that the prevalence of orf would be higher in lambs infected earlier with staphylococcal pustules; the data, however, did not support this hypothesis.

SUMMARY

"Plookie lammies" are young lambs afflicted with a benign pustular folliculitis sited either in the perilabial and perinasal areas of the skin of the head or in the skin of the perineum and ventral cauda. A few lambs have lesions at both sites and re-infections sometimes occur, The causative organism is a coagulase-positive beta-haemolytic Staphylococcus aureus. Epidemics occur annually in the flocks at Easter Bush.

REFERENCES

Fraser, J., Scott, F.M.M., Angus, K.W. and Martin, W.B. (1982). Experimental re-infection of the skin of sheep with Staphylococcus aureus. Vet. Rec. 111, 485-486.

McNemar, Q. (1969). Pyschological Statistics. 4th edn. Wiley, New York.

Parker, B.N.J., Bonson, M.D. and Carroll, P.J. (1983). Staphylococcal dermatitis in unweaned lambs. Vet. Rec. 113, 570-571.

Scott, F.M.M., Fraser, J. and Martin, W.B. (1980). Staphylococcal dermatitis of sheep. Vet. Rec. 107, 572-574.

Watson, W.A. (1965). The carriage of pathogenic staphylococci by sheep. Vet. Rec. 77, 477-480.

MAEDI/VISNA: THE ACCREDITED FLOCKS SCHEME

W A WATSON*

This paper

(a) outlines the salient features of the disease and its epidemiology;

(b) refers to the events in Great Britain following the recognition of Maedi Visna (M/V) leading to the introduction of the Accredited Flocks Scheme;

(c) outlines the Scheme;

(d) discusses progress and possible future developments.

THE DISEASE

Maedi and visna are Icelandic names given to 2 syndromes which occurred in sheep in Iceland between 1939 and 1965. During this period investigations demonstrated that both diseases shared a common viral aetiology. Maedi visna has now been recognised in many countries under a variety of names. In Denmark, Norway and Sweden in particular the first occurrence was associated with the introduction of Texel sheep.

Maedi (dyspnoea) develops as a progressive febrile pneumonia with loss of condition, despite the maintenance of appetite. Clinical disease is uncommon in sheep of less than 3 to 4 years of age. If an infected animal develops clinical signs, its condition will deteriorate slowly and it will eventually die; inter-current respiratory diseases are frequently present.

The lungs are enlarged, heavy and spongy with mononuclear infiltration of septa and hyperplasia of lymphoid tissue around the bronchi and blood vessels and hyperplasia of smooth muscle fibres.

Visna (wasting) develops in some cases if, following infection, lesions occur predominently in the central nervous system. In Iceland the condition was seen in younger animals, usually 2 years of age onwards. Early signs of stiffness of gait progressed to hind limb paralysis. Except for the Icelandic experience visna is a rare manifestation of the disease.

*Ministry of Agriculture, Fisheries and Food, Hook Rise South, Tolworth, Surbiton, Surrey.

THE CAUSAL AGENT

The virus has been classified as a lentivirus in the family Retroviridae.

The provirus is localised in the nuclei of macrophages in the lung and it is suggested that any stimulus which results in an influx of macrophages into the lung of a persistently infected animal may trigger virus replication and it is because of this that other lung infections may be important in the way in which maedi manifests itself in a flock.

A rather unique feature of maedi is that the virus mutates during the course of infection and the emergence of variants enables it to evade prevailing immune responses and contributes to the persistence of the agent in the individual and the population.

OCCURRENCE IN GREAT BRITAIN

The first evidence of M/V infection in GB was in the autumn of 1978 when sheep tested for export gave serologically positive results to the complement fixation test (CFT) in use at the time. The flock in question contained sheep previously imported from Europe, although they were not Texels. (Dawson et al, 1979)

Following the disclosure of infection owners were invited to submit blood samples for testing from imported breeds and their progeny free of charge so that an assessment could be made of the prevalence of infection.

Over 27,000 samples were tested and infection identified in 128 flocks (46 in Scotland).

The sheep which reacted were predominently Texels but evidence of infection was found in 11 other breeds and crosses. All of the 1280 reactors had contact with imported breeds or their progeny.

Subsequent testing of the flock in which infection was first detected has shown most of the older sheep to be serologically positive with an age related reactor rate and later in this flock histopathological lesions of maedi were detected and clinical evidence of the disease. (Dawson and Spence 1982)

A detailed investigation was carried out in 72 of the flocks in which reactors were detected up until April 1981. These were located in 23 counties in England and some Scottish regions and it was significant that by 1981 57 of the 72 flocks had sold breeding stock after introducing foreign sheep or sheep with a foreign parentage and these have been widely distributed in the national flock.

EPIDEMIOLOGY AND DIAGNOSIS

Before any effective control scheme can be devised for a disease the epidemiology should be understood and specific sensitive diagnostic tests available. In respect of M/V it is known that -

(a) infection may be transmitted by respiratory droplets, milk or blood;

(b) transmission between sheep at pasture is much less likely than between housed sheep;

(c) there is no evidence of transmission in semen or ova;

(d) following experimental infection positive serological results can usually be detected after 3 months although sero conversion may take longer with natural infection and possibly a small number of infected sheep never react positively to the blood test;

(e) the Agar gel immunodiffusion test (AGIDT) has been shown to be sensitive and specific (Dawson et al, 1982) although cross reactions do occur to caprine arthritis encephalomyelitis infection of goats (CAE). The 5 VI centres testing sera have shown a remarkable consistency in results with the Central Veterinary Laboratory.

THE ACCREDITED FLOCKS SCHEME

In discussion and with the agreement of the industry a voluntary Scheme was introduced for the registration of breeding flocks after a series of flock tests. The Scheme had to be made as simple as possible at minimal cost to attract members, but at the same time providing adequate safeguards to establish flocks free of infection and maintain them free. Unlike cattle owners, flock owners had no previous experience of disease control schemes.

- an advisory leaflet on M/V was prepared and issued to all interested flock owners and those with reactors;

- the Scheme introduced was voluntary and flock owners could withdraw at any stage;

- an advisory visit was paid to all intending participants to give guidance on the tests required and Scheme rules;

- because different risks were posed by exotic and indigenous breeds alternative testing programmes were devised for flocks to reach accredited status:

  (a) Indigenous. A private test of 25 per cent of the breeding animals followed 6 months later by an official test on all sheep over 9 months of age.

  (b) Exotic. A private test on all sheep over 9 months of age followed by an official test after 6 months and a further official test 6 months later;

- all breeding animals failing the test to be removed for slaughter with an option to retain the progeny of reactor ewes in isolation with further testing;

- sheep introduced from other flocks of lower status only after a period of isolation of 6 months in the case of indigenous and 12 months in the case of exotics with 2 and 3 clear tests respectively;

- separation of Scheme and non-Scheme sheep on the same farm;

- reporting of respiratory or nervous signs in sheep over 2 years of age;

- separation of Scheme and non-Scheme sheep at markets and shows.

PROGRESS OF THE SCHEME

Texel flocks were the first to enter the Scheme but these were rapidly followed by other breed societies.

By 21.3.84 there were 350 accredited flocks and a total of 1,462 flocks in the Scheme.

PROBLEMS ARISING AND REVISION OF SCHEME REQUIREMENTS

Difficulties arose in flock owners appreciating the requirements of the Scheme when some preliminary visits were not carried out until the results of a clear private flock test had been submitted.

The guidelines drawn up for the separation of different categories of sheep at shows and sales reflected our knowledge of the transmissibility of infection. Clarification of these was frequently necessary and preparation and issue of booklets of movement permits to accompany sheep indicating their status.

Major difficulties arose when sheep were marketed in the autumn of 1982 as Scheme sheep were mixed with non-designated sheep at sales and introduced into purchasers' flocks without going through the isolation and testing procedures. To overcome these problems new rules were introduced which permitted the animals to remain in the flocks and the status was down-graded introducing additional testing requirements before they became accredited. This procedure also enabled flock owners to use rams immediately avoiding lengthy isolation.

With a new Scheme supervised by a large number of different DVOs there were difficulties in achieving uniformity of approach. Problems arose in keeping to the required interval between flock tests and because of the race towards accreditation and the benefit this gave owners at sale time it became necessary to adhere strictly to a minimum interval between tests of 180 days.

With agreement with the industry the Scheme rules have been revised and requirements are indicated in Fig. 1.

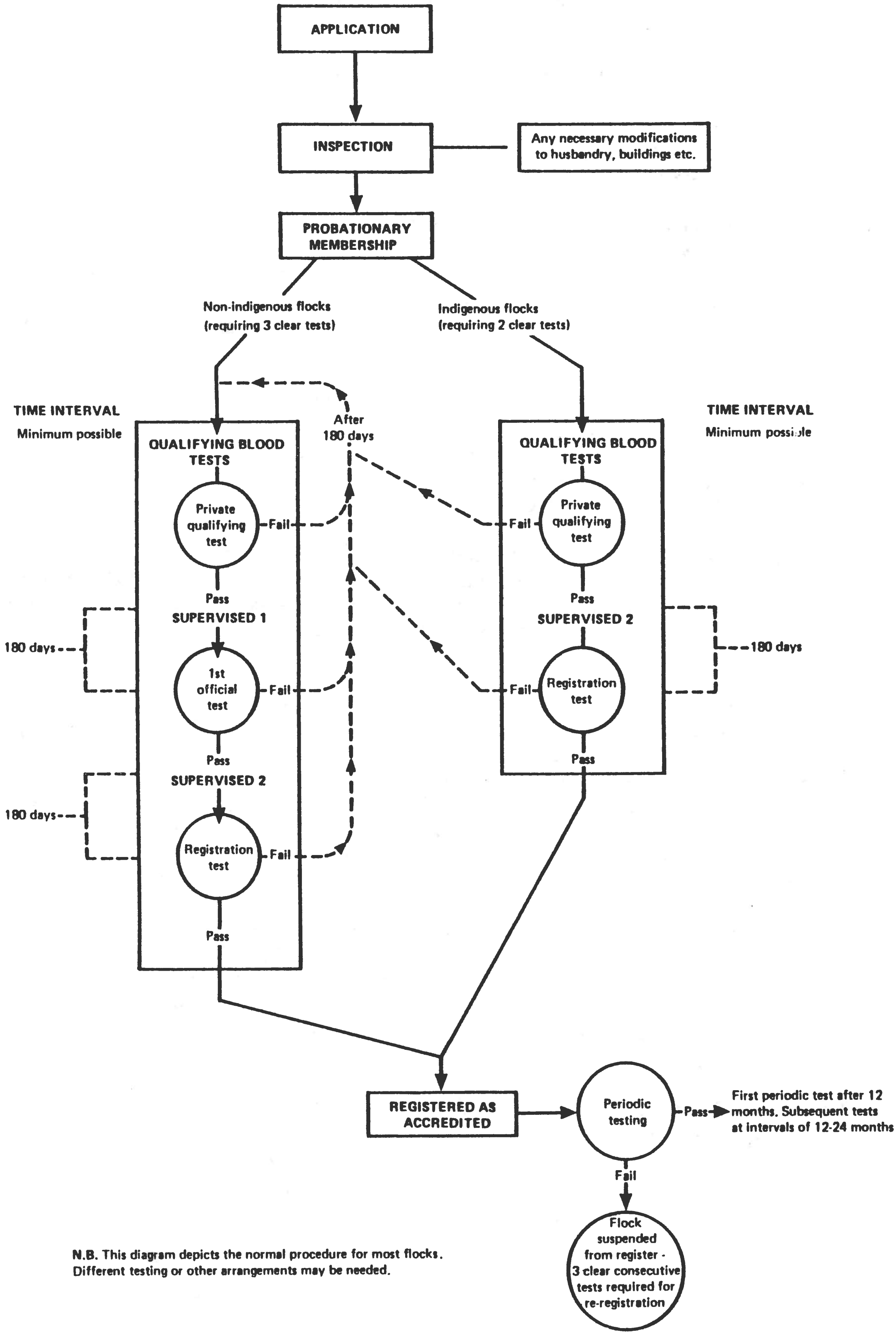


Fig. 1 The requirements of the Maedi Visna Accredited Flocks Scheme

- applicants become probationary members after a preliminary visit and inspection;
- all sheep, and not just those over 9 months of age, now have to be identified;
- the facility to add sheep to flocks without them going through the isolation procedure has been withdrawn;
- some modifications have been made to the requirements for the isolation and testing of the progeny of female reactors to make these less onerous;
- following the recognition of CAE in this country the requirements for Scheme members with goats and sheep on the same premises have been clarified;
- markets are now being approved on the basis of layout and separation and markets for Scheme sheep are supervised by veterinary or animal health officers.

FUTURE DEVELOPMENTS

Throughout the Scheme testing programme relatively few reactors have been detected. Nevertheless it must be recognised that many detected during the survey were probably not slaughtered and were sold into non-infected flocks.

It is of significance that in 1983, 3 cross-bred flocks of indigenous breeds were detected with a high prevalence of reactors and some evidence of clinical disease.

It is probable that M/V will continue to spread slowly in pure bred and cross-bred flocks perhaps quickly reaching a high prevalence in some of these associated with clinical disease. This could be exacerbated by the popularity of housing and the presence of other respiratory infections.

The nucleus breeding flocks in the Scheme are likely to remain maedi free and there are stringent controls to prevent the possible re-importation of infection from abroad.

Breed society requirements will keep up the pressure to increase the pool of accredited flocks as will greater numbers of sales for accredited sheep only and a premium for these. This will extend the veterinary resources available for servicing of flocks.

The impossibility of launching a national eradication programme remains unchanged - the need to test most or all of the adult sheep population, the difficulties associated with delayed sero-conversion after infection and the expense in relation to possible benefits.

REFERENCES

Dawson, M., Chasey, D., King, A.A., Flowers, M.J., Day, R.H., Lucas, M.H. and Roberts, D.H. (1979). The demonstration of maedi/visna virus in sheep in Great Britain. Vet. Rec. 105, 220-223.

Dawson, M., Biront, P. and Houwers, D.J. (1982). Comparison of serological tests used in three state laboratories to identify maedi/visna infection. Vet. Rec. 111, 432-434.

Dawson, M. and Spence, J.B. (1982). Maedi/visna infection in sheep. Veterinary Annual No. 22, pp 120-128.

A STANDARD ADVISORY SYSTEM FOR LOWLAND SHEEP FLOCKS

W HOLLAND*

This paper describes an advisory system for lowland sheep flocks engaged in fat lamb production. The system has arisen over the last decade or so, in parallel with similar systems devised for dairy herds, beef units and pig units, stimulated, in my own case, by a combination of self-interest and personal interest. Self interest, in that, given an increase in the breeding sheep population in the region over the last twelve years and, of late, a good stable price structure for the end product, work could be generated by the development of a comprehensive advisory system, and mental stimulation enhanced. Personal interest resulted from a determination to avoid, and a strong antipathy towards, the still current practice of dispensing casual verbal advice. The results obtained by the latter on ill-informed idleness, are not subject to analysis, are at best, harmless, at worst harmful, and rarely of lasting usefulness to anyone concerned. Historically, the concept of a whole flock system, based on pre-arranged discussion and advice, complemented by full, written reports, and further advice as required, took shape following my involvement with an 'in depth' and prolonged study of sheep flocks in Northamptonshire initiated, carried out and subsidised by the Meat and Livestock Commission between 1971 and 1974. No part of the work is original; it is a compilation of material which others have published at various times, or have personally communicated.

From 1975 the county of Northampton submitted to the plough. Dairy herds and beef units disappeared with depressing regularity. This created, surprisingly, a demand for systematic veterinary advice for both sheep and beef units, because, strive as they might to plough, many farms were left with unploughable grassland and usable empty buildings. If stock were to be kept, then the productivity of the enterprise had to be raised. Systematic advice was on many occasions sought. Since 1979 the system has been applied to sheep flocks, and subjected to expansion and refinement. It appeared to be flexible, able to accept compromise to suit individual flock requirements, and is useful, whether applied as a whole, or in part. Several thousand breeding ewes are currently involved, to a greater or lesser extent.

The next section of the paper presents requirements for discussion with flock owners and shepherds, and a case history of reports, compiled for a particular flock during its first advisory year. It it important during preliminary discussion to evaluate management's potential since this will determine the 'depth' and 'rate' at which advice can be given. Systems do not work without willing and informed acceptance.

The preliminary discussion

This should follow a pre-determined set pattern in order to obtain the required information relating to current flock status and management procedures. Ascertain ram and ewe breed(s), status, numbers, and current approach to feeding, breeding, pasture management and disease control. Inspect

*The Avenue Veterinary Hospital, 33, St. Peter's Avenue, Kettering.

flock buildings and WALK THE PASTURE. Obtain available records relating to performance and a large scale map of the farm, with current and projected crops and acreage. With the help of this information, discuss and set achievable targets, for example:

1. Identification system.
2. To breed or buy?
3. 200% lambing?
4. Clean pasture?
5. To house ewes (or not)?
6. Standardise feeding?
7. Time of lambing,
8. Shorten lambing time?
9. Bring ewe flock to required level by breed, age and quality.
10. Select rams of right breed, quality and numbers as terminal sires.
11. To understand and carry out BODY CONDITION SCORING.
12. Establish a system of disease control
13. Keep records.

Assess for control:

1. Clostridial diseases.
2. Pasteurellosis.
3. Orf.
4. Infectious abortion.
5. Foot rot.
6. Mastitis.
7. Swayback
8. Mineral deficiencies.
9. Pregnancy toxaemia.
10. Trace element deficiencies.
11. External parasites.
12. Internal parasites.

A preliminary report should set out these procedures as simply as possible, in time sequence, and by prior arrangement further advisory visits should follow, with reports in detail, appropriate to the season. A flock file should be set up at this time, to hold written reports and literature. These should be duplicated as required to both flock owner and shepherd. The timing of advisory visits should be fixed to coincide with seasonally important events.

Visit 1: Mid to late summer
(At least 6 to 8 weeks before tupping)

1st culling procedure: Cull on body condition score, records, udders, legs and feet, and mouths. The flock to be managed to give individual body condition scores of 3.5 for ewes and 4 for rams at tupping. Cull ewes, at tupping, with body condition scores of 2 or below.

Animals should be kept on a rising plane of nutrition up to tupping, which should be maintained for 40 days post-tupping.

At service:

1. Group size: no group to exceed 200 ewes
2. Restrict acreage when tups are turned in
3. Do not use tups in pairs
4. Use 1 tup per 40 ewes
5. Do not use ram lambs with maiden ewes
6. Use raddle and keep records

Visit 2: The pregnant ewe

Management and nutrition are vital. Feed concentrates from day 105 of pregnancy. Feed concentrates from 0.25 to 2.2lbs/ewe/day to reach 2.2 lbs/ewe/day at 14 days pre-partum.

NOTE: High energy/protein ration required.
Balance rumen degradable and rumen non-degradable protein.

Balance hay,silage, straw forage and cereal ration.
Vitamin/mineral supplements to be given, as advised.

When the flock is to be housed, evaluation of available buildings is necessary. Specific advice and reports should be submitted with simple line plans of buildings and penning requirements.

Visit 3

This can be combined with Visit 2 where appropriate. It is at this time in particular that maximum management and labour effort is required, with every birth supervised by observation, with interference when needed. All ewes should be at optimum body condition, with the feeding regime carried out as advised. All lambing pens and equipment should be prepared and ready for use before lambing starts. All procedures, relating to both ewes and lambs, should be followed as advised, including anthelmintic treatment of ewes, when recommended.

Visit 4: Post lambing

It is in this area that the benefits of pre-planning advice are most apparent. Move ewes and lambs to pasture as quickly as possible after lambing. Move in small groups. move to clean pastures if possible. (Note: pre-planning requirement). Advise on pasture classification: 'Clean', 'Safe' etc.

Provide:	(adequate food for the lactating ewe
	(sufficient watering points
Note:	(shelter for lambs
Pre-planning	(creep feeding as soon as possible
requirement	(field divisions; temporary fencing

Pasture management

Note:	(pasture usage: set stocking etc.
Pre-planning	(stock density
requirement	(conservation (aftermath)
	(parasite control
	(fertilizer usage
	(species variation (cattle)

The management of rams should receive attention. Each ram should be phsically examined, and steps taken to ensure that rams are kept in good health and body condition.

Since an advisory programme is envisaged as a continuing procedure, it is important that provision be made for succeeding years and updating be carried out. For example:

Future programme:

1. New techniques
2. Critical analysis of value of current techniques
3. Sheep file: literature update
4. Specialist help and advice
5. Collection of information from flocks
6. Assess results
7. Correction for under-achievement

With reference to collection of information, all flocks are asked to complete a simple information sheet in the early summer (see below). Because it is simple, most flocks eventually return it. If more comprehensive information is required, a special effort needs to be made to obtain it.

INFORMATION SHEET

1. RAMS Nos. Breed(s)
   - rams
   - ram lambs
2. EWES Nos. Breed(s)
   - ewes
   - ewe lambs
3. EWES TO TUP
   Nos. and Date
4. EWES LAMBED
5. LAMBS BORN
   - alive
   - dead
6. LAMB DEATHS BETWEEN BIRTH & WEANING
7. LAMBING COMMENCED - Date
8. LAMBING COMPLETED - Date
9. EWES HOUSED/HOUSED AT LAMBING/NOT HOUSED
10. RATION
    a) ewes
    b) lamb creep
    c) lamb fattener
11. LAMB SALES
    a) commenced
    b) completed
12. COMMENTS ON:
    a) Results
    b) Problem areas
13. COMMENTS ON MASTITIS IN EWES
    a) known cases this year
    b) previous culling percentage
14. CONDITION SCORING FULLY PRACTISED & UNDERSTOOD?

The final section of this paper is a case history of reports actually submitted to a breeding flock (W.H./12) during 1982-1983. The flock had existed for many years with minimal veterinary input. When advice was sought in April, 1982, practically the only information available was that there were 400 ewes, of which 83 were barren, with a lambing percentage of 120. Several ewes had died during the lambing season from hypo-magnesaemia.

Report 1. April 1982 Flock W.H./12

PRELIMINARY REPORT

RAMS: Suffolk rams will do nicely at the moment. If we get any marked change in current E.E.C. pricing policy it may be necessary to consider a move towards, for example, Texels or Charolais, but there is ample room for flock improvement without considering any change as yet. Six new tups should be purchased this autumn at lease 8 weeks before expected tupping dates.

EWES: The only information we have about the ewe flock is that there has been a reasonable programme of replacement and no further purchases will be required this autumn. For the next three years, replacements should be high quality shearlings as discussed, and confined to the following breeds:

1. Mules, Blue faced Leicester x Swaledale
2. Mashams, Teeswater x Dalesbred ewes
3. Greyface, Border Leicester x Black faced ewes or North country horned.

If the variation of the ewe flock and culling procedures are carried out as we discussed (see my following report) then we would envisage an average annual replacement to 1/5th to 1/6th of the flock.

Report 2. April 1982 Flock W.H./12.

REPORT ON SHEEP FLOCK

I would advise the following:-

1. MAJOR CHANGES IN POLICY

(a) To upgrade the status of the flock over the next 3-4 years by buying good quality replacements as suggested.

(b) To house the ewes from Christmas onwards.

(c) To set a definite target date by which time all lambs born during the season should be sold; if not fat, sold as stores.

(d) To devise a more efficient and accurate method of feeding the pregnant and lactating ewe.

(e) Abandon the current policy of breeding replacement ewe lambs.

2. PRE TUPPING MANAGEMENT - Report 2a June 1982

All ewes should be handled and any ewes with a body condition score of 2 or below should be discarded. Ewes with body condition scores of 2-3 should be drawn off as a separate group and given preferential treatment, with the idea of achieving whole flock body condition scores of 3.5 at tupping. A further examination of ewes on an individual basis should take place a week or so before tupping commences. Thin ewes should be less than 5% of the flock and should be discarded since it is in this group of thin ewes that we will find the highest proportion of ewes that are barren or give birth to single lambs, neither of which is required. Tups should all be in good condition with body condition scores of at least 3.5 and preferably 4; they will inevitably lose weight whilst at work. I would suggest a ram to ewe ratio of about one in 40, splitting the flock into two groups and using tups in threes. The tups should be kept away from the ewes until the day of introduction. The flock should be kept on a restricted acreage so that the tups are not travelling over extensive areas searching for ewes. At tupping the ewes should be in a rising condition on a rising plain of nutrition which should be maintained for 40 days after tupping.

3. SERVICE MANAGEMENT - Report 2b June 1982

Raddle Day 1. Change raddle after 8 days.
Change raddle after 17 days.
Remove tups at 34 days optimum and definitely by 51 days.

Use chaser tup with different raddle from 51 days for five weeks. 3rd cull - The chaser ram will pick up all returns over the five weeks. Ewes marked and tupped by the chaser for the first time could be pregnant but all other ewes and non-marked ewes should be sold as barren - see enclosed table.

Since there will be a different time for lambing for each raddle group, consideration should be given to separation of raddle groups, because the time to start feeding pregnant ewes will vary. Feeding should start 105 days after the raddle change for that group, providing the ewes are in good condition at tupping and their body condition is maintained for 40 days. Some loss of body weight is allowable in the first three months of pregnancy. However, this should be checked ten to eleven weeks after tupping and if the proportion of ewes losing body weight is more than 10% then extra grazing should be made available or extra hay fed.

Report 3. April 1982 Flock W.H./12

CONTROL PROCEDURES

1. Clostridial Diseases
   The flock is at the moment within a vaccination system. Please remember that newly added sheep of unknown vaccinal status require vaccination when entering the flock. Two doses as per the manufacturer's instructions with the usual third dose two to four weeks before lambing with the rest of the flock. Remember that rams also require vaccination.

2. Orf
   Can you please let me know whether there is any record of cases in the previous twelve months and whether there is any orf currently active in the flock?

3. Contagious Abortion
   We have no knowledge of any recorded instances in this flock and at the moment I suggest we take a calculated risk and await events. I am discussing this matter with The local V.I staff and will advise further.

4. Foot Rot
   Hopefully this is not a significant problem in the flock at this moment, very largely due to low stocking densities. Until we arrive at a more accurate level of infection I would not recommend a foot rot vaccination programme. However, the usual foot care procedures, including regular trimming and paring of feet, should be carried out.

5. Sway Back
   There is a possibility that sway back may occur. The "random" use of copper injections in pregnant ewes that are housed can be more hazardous than the use of copper injections in ewes at pasture. I suggest that random blood sampling to check on copper levels when the ewes are ten weeks pregnant may be advisable.

6. Mineral Deficiencies
   (a) Calcium and Phosphorus - A problem mainly with the heavily pregnant and newly lambed ewe. Calcium and phosphorus levels and calcium and phosphorus ratios should be evaluated from the total ration.

(b) Magnesium - magnesium deficiency has been a problem in the past in this flock and supplementary magnesium feeding should be considered as an addition to the ration in late pregnancy and for a short time following lambing.

7. Twin Lamb Disease
If we manage to achieve an adequate feeding regime for the pregnant ewe, instances of this disease should be minimal.

8. Trace elements and vitamin deficiencies
These should not cause a problem if adequate levels of trace elements and vitamin additives are included in the ration. I would suggest that whatever additive is used, it should contain selenium at the appropriate level for sheep.

PREVENTIVE MEDICINE

9. External Parasites
To be controlled by clagging, dipping and spraying as appropriate.

10. Internal Parasites

(a) Liver fluke - we have no positive evidence of this disease in the flock, and I propose no further action at the moment.

(b) Tape worms - Of significance only with intensive early lamb production; no further action at the moment.

(c) Round worms - The control of round worms in the flock is probably the most important flock health procedure. I feel that we should be able to establish a clean/safe pasture system of grazing which will be of considerable help to us. This is definitely one for further discussion.

Report 4. August 1983 Flock W.H./12

THE EWE FLOCK - LATE PREGNANCY

FEEDING

Cereal feeding to commence round about 105 days pregnant, starting at 0.75 kg. increasing to 1 kg. two weeks before lambing. Since we are hoping for a heavy lamb drop, I would suggest that protein levels should be in the 16% range with adequate rumen non-degradable protein. Hay should be fed initially more or less to appetite. Since we are not certain of the nutritive value of the hay, energy and protein requirements provided by the concentrate feeding will be particularly important. It may be necessary to ration the amounts of hay fed in late pregnancy as the concentrate feeding increases. If hay is fairly freely available, hay rack space will not be of vital importance, but allow something like 10" per ewe. The trough space for feeding concentrates is of considerable importance and a minimum of 18" per ewe should be allowed. Troughs should be filled as quickly as possible. Since we expect the ewes to be housed through the latter part of pregnancy, you may think it preferable to feed the ewes in the big barn on the concrete apron (see enclosed sketches).

Ensure that a supply of fresh clean water is always available.

Report 5 September 1982 Flock W.H./12

EWE FLOCK - LATE PREGNANCY

The use of home grown barley is sensible. Feed whole grain.

The ration has been discussed with the nutritional chemist of your food supplier, who will provide a 'ewe pencil' as a barley balancer for the ewe ration.

Report 6 November 1983 Flock W.H./12

SHEEP HOUSING

1. The large open plan corrugated barn can be conveniently divided into three (as discussed), each pen to hold 85 ewes. This is rather large grouping, but since there is no possibility of getting down to groups of 35 to 40 it will suffice. I would suggest that the end of the barn and the side that is partially open at the moment be made fully open with cover to a height of 4' to 4'6". Adequate water should be supplied, and 18" of trough space should be made available to each ewe. We have no knowledge of the nutritive value of the hay and this should be fed initially more or less ad lib., allowing a rack space of about 10" per ewe. As the ewes approach late pregnancy and maximum concentrate intake, it may be necessary to reduce the hay ration. There should be sufficient space to leave the ewes permanently housed until lambing, but if 10' gaps are incorporated as per the enclosed sketch and if sheep netting were used to enclose the outside concrete pad, it would be possible, providing labour and time were available, to feed the ewes with one group following another on the concrete pad. I suggest this as a possibility, because one of the problems of feeding cereals to the ewes with the troughs inside the pens will be the considerable tussle that always follows when sheep are trough fed. If the outside area is used the troughs could be set in echelon and the sheep let out in groups to "full troughs".

2. I note that the tiled barn which we were considering for housing the ewes is still occupied by cattle. However, if the lower half of this barn is used and the walled yard in front of it is also used, this could be divided again into two or three and should be perfectly satisfactory to hold another 100 to 120 ewes. I think to do this it would be reasonable to remove as many as possible of the boards which face the open yard to "open up" the barn. The same requirements, i.e. 14 square feet per ewe laying area and 18" trough space etc., will apply.

Report 7 February 1983 Flock W.H./12

LAMBING (HOUSED)

This is the time when maximum management and labour effort is required, preferably with every birth "supervised" by observation with interference when required.

THE EWE

1. I would expect all ewes to be in good body condition. Body condition scores 3.5, except for the small group of ewes which have been separated off as below par.
2. The feeding regime as directed should be carried on and every effort made to avoid change.
3. Any ewes becoming dull, losing their appetite and becoming partly or wholly recumbent, should be dealt with by standard procedures as discussed. Animals which fail to respond should be referred back to me.
4. Ewes which have difficulty in lambing and require assistance should be lambed, hopefully at knee or waist height as discussed. If assistance is not successful after fifteen minutes manipulation consider seeking professional advice. All ewes that are assisted should be injected as advised.
5. Lambing pens to be set up as arranged for individual ewes paying particular attention to routine hygiene and cleaning.
6. Check all ewes' udders and teats at delivery.
7. All lambs to be dried in cases of multiple births if the ewe is still lambing.
8. Make sure the ewe/lamb bond is established and all lambs are lively and they suckle in the first two hours after birth.
9. Make sure that the fostering procedures are adequate and fully utilised. I would rather have too many triplets turned out than large numbers of single lambs.
10. Worm all ewes on day 2 or 3 whilst still in the holding paddocks before moving to clean pastures.

. . . .

LAMBS

1. Check each lamb at birth to make sure it is physically normal, i.e. mouths, navels and anus.
2. For normal lively healthy lambs no procedures are carried out on day one except routine injections of long acting antibiotics as directed.
3. On day 2 docking and castration of normal lambs before turning out into the holding paddocks in small groups as discussed, e.g. Day 1, Day 2, Day 3.
4. High Risk Lambs
   (a) lambs from young ewes;
   (b) twins;
   (c) triplets;
   (d) small lambs;
   (e) premature lambs;
   (f) lambs that are weak at birth.

Birth to 5 hours

(a) Wet new born lambs can lose heat quickly. Dry them using towels. Do not be too rough and help lambs to suckle as soon as possible.

(b) Heat loss may still be excessive due to chilling and inadequate intake of colostrum. Check rectal temperatures with clinical thermometer as directed. If the temperature has fallen from 39^0C to 37^0C. (102^0F to 99^0F) the lamb is at risk. Make sure that is is dry and feed colostrum as directed by stomach tube. Feed three times in 12 hours:-

Large lambs	Small lambs	
200 mls	100 mls	per feed

(set up nest of boxes with overhead lamps as directed)

10 Hours to 3 days

Lambs that have become weak due to chilling and inadequate feed intake: their blood glucose levels will be depressed and they will not respond to feeding by stomach tube and warmth alone. Check by rectal temperatures. If the rectal temperature is below 37°C (99°F) or less, inject glucose by intra peritoneal route as directed, i.e. 20% solution of glucose at body heat, at a dose rate of 10 cc per kg. and then place in the warming box. Once its body temperature rises above 37°C (99°F) it should be removed from the warming box and given colostrum by stomach tube before returning to the ewe.

These procedures may be necessary in lambs up to three days of age (particularly triplets) and may have to be repeated with individual lambs.

Please note that by following the enclosed procedures and by using rectal temperatures as a guide, we should be able to reach a more accurate assessment as to which course of action to adopt.

LAMBING PACK

EWES

1. Mineral injections
2. Long acting antibiotics
3. DAL lambing tool
4. Obstetric lubricant
5. Syringes and needles as required
6. Arm length disposable gloves
7. Anthelmintics

LAMBS

1. Thermometer
2. Routine long acting antibiotic injection
3. Antibiotic aerosol
4. Stomach tubes
5. Dextrose solution
6. Syringes and needles as required
7. Scour medicine?

ALSO HAVE TO HAND:-

1. Lambing pens and adequate feeding and water for ewes
2. Warming box
3. Fan heater
4. Replaceable cardboard boxes
5. Ewe colostrum in containers
6. Cow colostrum in containers
7. Supplementary heat
8. Adequate light
9. Power point
10. Electric kettle
11. Fostering equipment
12. (Extra labour to avoid shepherdess becoming tired??)

Report 8a March 1983 Flock W.H./12

Please find enclosed the programme and sketch plan (Fig.1) for both cattle and sheep. You are extremely fortunate in being able to have a complete clean pasture system based on grazing sheep one year and cattle the next and "never the twain shall meet". If, due to unforseen circumstances, the system has to be "broken" could you please let me know?

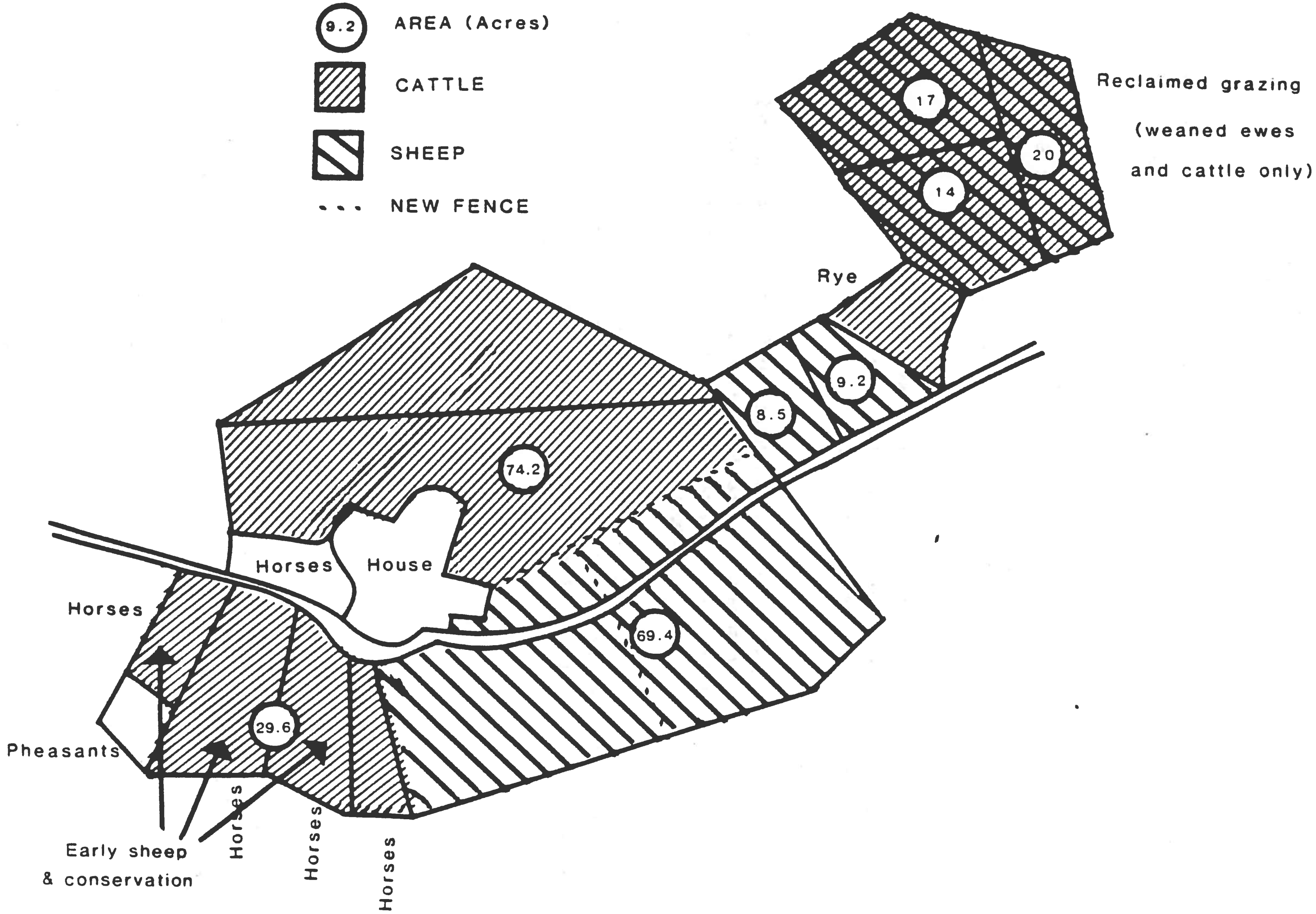


Fig. 1 Sketch plan for grazing of flock
W.H./12 for 1983/84.

Report 8b March 1983 Flock W.H./12.

GRAZING PROGRAMME 1983/84

Turn ewes and lambs out on to rye grass as provided. They should then go on to the new seeds and "pheasant" areas. (When they have finished grazing the rye grass it can either be ploughed and seeded with more grass or continental turnips.)

Once the lambs are strong enough and the parkland grass has started growing, shut off the early grazing and fertilize for conservation. The sheep should go on to the parks as marked on the enclosed sketch. You should consider lamb creep for the earliest possible sale of lambs.

The young cattle should go straight on to the parks as per sketch plan. It may be necessary later in the summer to give supplementary feeding to maintain growth rates. Any overgrowth of grass should be controlled by "topping" later in the season.

There is a marked need for grassland improvement in several areas which will be helped considerably by controlled grazing and measures to control overgrowth as previously discussed. Some form of electric fencing will be essential.

I would point out again that the areas must be totally segregated as far as species are concerned - no sheep on cattle areas and no cattle on sheep areas until the spring of 1984. Considerable conservation of grass will be required until stock numbers are increased.

Once the system is established it may be helpful to the estate if we had further discussion on the economics of the whole situation, because it seems to me at the moment with current stocking densities that the area could be under-utilised.

A COMPUTERISED SHEEP FLOCK HEALTH PROGRAMME

R.J.W. PLENDERLEITH*

The Glasgow University veterinary practice is a 5-person mixed, mainly agricultural practice centred in the market town of Lanark. It is run as a separate self sufficient economic unit. Final year students attend in groups of four of five for fourteen days.

The practice has a 64K Tandy Computer mainly for accounting and dairy herd fertility programmes. The use of the latter is more limited by veterinary hours available than by farmer demand. A word processor is also in use.

The practice services 120 sheep flocks - 67 lowland and 53 marginal/ upland flocks. Of these 120 flocks, 63 (52.5%) receive vaccination advice and supplies. As might be expected, 43 (64%) are lowland and 20 (38%) are marginal flocks. Thirty five farmers (26%) receive anthelmintic advice and supplies, and only 12 (10%) get advice on mineral supplementation and supplies.

These figures illustrate the problem of getting even basic sound advice to one's clients in the face of massive price discounting on drugs, which seems to be the farmers' main concern. The high price of sheep meat, in fact, does little to induce them to higher productivity or to seriously attempt to lower the national annual ewe mortality figure from 4%, and the national annual lamb losses from 12%.

In my last practice in Lincolnshire, flock health programmes were carried out on a very basic level by supplying a number of clients with a personal book incorporating a calendar of action lists for each month for his particular flock. The natural progression from this was to develop a computerised sheep health programme.

The main problems in establishing a computerised programme are:

1) Resistance to change

Although the dairy and pig farmers are convinced of the natural progression of computerisation, the sheep industry is more conservative and resistant to change. Information gleaned might be too illuminating and affect vested self interests.

2) Identification

a) Ear Tags These still produce problems due to losses. Dalton Roto (Dal 6) were used by G.H. Yeoman of Beechams Labs (personal communication) on 1000 ewes and lambs on a copper needle trial over a limited period with good success. They can also be colour coded.

*University of Glasgow Veterinary Practice, Lanark.

b) Transponders The development of small electronic transponders implanted below the skin of the animal with an automatic implant gun appears to be the best hope in the future in recording and in national disease control (Holm, 1981). At the moment these can be read at 3m by an interrogator/receiver and can give information on species, farm of origin, owner of flock, animal number, date of birth, and temperature of animal. Obviously the development of such transponders will be dependant on economical and political factors.

The aims of a flock health programme are to:

a) reduce mortality and morbidity;
b) determine economic and proper use of feeds;
c) determine economic and proper use of drugs;
d) insure against serious losses;
e) increase productivity;
f) collect marketing information;
g) facilitate genetic improvement;
h) increase veterinary involvement and job satisfaction;
i) eventually, provide national disease information to help planning of the application of financial resources, and to help in national disease control schemes (eg maedi visna).

Our programme was practically completed and was lost when the computing company went into liquidation. This means re-writing the programme.

It will consist of:

a) Farm File. This will have information about the farmer, his stock and also set production targets.

b) Nutrition File. This will contain information about the various feeds, and output the needs of and advice for the farmer for feeding at tupping, during pregnancy (stage and number of lambs), and lactation, depending on the number and weight of the sheep and the price of feeds.

c) Disease Control File. This will contain lists of essential and optional records of diseases which will be entered into the individual farm file after discussion with the farmer, and according to his needs.

d) Monthly Action Sheets. These are dependant on b) and c) and will be issued as reminders, and drugs supplied when necessary and required.

e) Weight Recording Eventually it will be desirable to record the weight of lambs at birth and marketing. Information on wool and meat prices will also be useful. Obviously, the more information is available, the more help there will be in making policy decisions and eventually in genetic improvement.

REFERENCE

Holm, D.M. (1981). Development of a National Electronic Identification System for Livestock. J. Anim. Sci. 53, 524-530.

INFORMATION GATHERING

OWNER INTERVIEW SURVEYS AS A BASIS FOR ESTIMATING ANIMAL PRODUCTIVITY AND DISEASE IMPACT IN DEVELOPING COUNTRIES.

B.D. PERRY* and E.H. MCCAULEY**

The need for relevant and accurate information on animal disease is not novel, and has been defined by many authors. This data is used both by governments in the planning of disease control and research programmes, and also to a lesser extent by individuals in evading or controlling disease outbreaks. Indeed, while developed countries have until recently been predominately concerned with individual animal services, the use of population surveillance and control techniques has always predominated in developing countries, due principally to the constraint of limited resources.

In recent years, the progressive control of epidemic infectious disease in developed countries has led to an intensification of effort to detect the effect of less dramatic disease entities on animal productivity. This has produced a variety of surveillance techniques at the herd or population level. It has also produced the realisation that many epidemic conditions less dramatic than rinderpest for example are economically adverse.

In many developing countries, the major infectious diseases of livestock still predominate, and the need for a surveillance system for these certainly exists. However, in most areas the endemic, well-recognized syndromes may present more of an economic limitation to livestock production in the long term, and it is essential to bring to the attention of governments and other donor agencies what these entities are, to what extent they exist, and what is their socio-economic importance in relation to other problems of animal health. Furthermore, the support and development of an infrastructure to control the endemic production-related conditions is more likely to be of long term benefit in control of epidemic disease than the recurring "fire-engine" approach.

SURVEILLANCE SYSTEMS

Disease surveillance systems in current use have been described and discussed by many authors, but these reports are principally restricted to those used in developed countries. In

*Virginia-Maryland Regional College of Veterinary Medicine, VPI&SU, Blacksburg, Virginia 24061, USA.

**Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Minnesota, St. Paul, Minnesota 55108, and Big Timber, Montana 59011, USA.

them, the survey usually plays a limited, but carefully defined role in gathering additional data in preparation for a disease control programme.

In developing countries, the conventional sources such as diagnostic laboratories, slaughterhouses, and monthly departmental reports are less effective surveillance tools due to a variety of factors. Diagnostic laboratories receive samples from a small private or commercial sector that can afford or have the logistic means to submit samples. State support for sample processing tends to be for funded disease surveys or, when appropriate, for a particular disease campaign, and are therefore limited due to the restricted resources available for these activities. Some data are available from slaughterhouses, but these are usually a limited source which taps the commercial sector. The large majority of the livestock population is slaughtered privately in the countryside, from which no data are gathered. Monthly or annual reports from district or regional veterinary officers are often valuable, but anecdotal in nature, with a high degree of variation in consistency and quality. Nor do they usually give any representation of the area covered, but indicate the presence of new diseases. As such, there is very little assessment of the extent and impact of these diseases. This "level" of disease is very difficult to assess. The commonest technique is the use of infection prevalence data. However, while this is of great value for some, such as tick-borne diseases, where levels of enzootic stability are important in the determination of cost-benefit relations, it is of little value assessing the impact on production, as it simply tells that animals have been exposed to an agent, revealing nothing of the outcome of infection.

Some countries have developed surveillance systems based on regular reporting of disease by veterinarians or veterinary assistants on a carefully prepared proforma sheet. In some instances, these data are collected concurrently with certain production parameters, but this is uncommon. Regrettably, some of these seen by the authors are far too long and complicated for the level of information to be collected and thus have a tendency to create confidence that does not exist. When this is coupled with the fact that field personnel may not appreciate the justification for collecting these data, the rates of completion and return and the extent of reporting are low.

The survey approach has therefore taken a more prominent role in health and productivity surveillance in developing countries, often greater than its limited and defined position in developed countries. A few of the reported surveys have included an owner-interview survey component (Nuru and Dennis, 1976; Schwabe and Kuojok, 1981; McCauley et al., 1983; Sollod and Knight, 1983; Perry et al., in press).

The aim of this paper is to describe the relative value of the personal interview, or questionnaire survey, designed to elicit retrospective information from livestock producers.

USE OF OWNER INTERVIEW SURVEYS

Questionnaires have been used extensively in epidemiological surveys but most of the published comment on these relate to the use of postal questionnaire surveys, which have virtually no application in developing countries. The personal interview of livestock owners, however, has considerable application in such areas, in the gathering of retrospective data on animal health and production.

Circumstances of use.

Surveys carried out in isolation, without being part of a larger programme of animal health or livestock production improvement, are likely to succeed once, or even twice, but subsequently are unlikely to be tolerated by livestock owners, and efficacy will diminish markedly. This has been observed in Haiti (Perry, unpublished), where some owners indicated that it was time for the surveys to stop, and the actual programs to start! Biggs (1980) presented a methodology for an agricultural technology development programme in the Himalayas, of which a producer interview survey was a key component. In the field of animal health, encouraging results have been obtained when the survey was only one component of a larger programme, such as bovine schistosomiasis control in Sudan (McCauley et al., 1983a). In this instance, the development of a vaccine against S. bovis stimulated concern over the cost-benefit relationship of vaccination, which led to an owner interview survey to establish cattle morbidity and mortality statistics.

The authors consider the technique appropriate for the gathering of data on specific disease entities, and on the more general subjects of performance and productivity. On specific diseases and clinical signs, it is important that they are well defined and recognizable by the livestock owner. This ability will vary from region to region, depending not only on the severity and epidemiology of the disease, but also on the presence or absence of other conditions with which it may be confused.

It may be necessary to carry out preliminary studies which attempt to assess the owners diagnostic ability with the disease or diseases being surveyed by clinical, post mortem and/or laboratory examinations. This was required in the case of bovine schistosomiasis (McCauley, et al., 1983a).

The use of specific clinical signs as indicators of production loss has recently been reported from central Africa, where a high degree of correlation was found in cattle between knee hygromas and abortion caused by brucellosis (Domenech, et al., 1982). The authors derived a mathematical relationship between these conditions, allowing the estimation of economic losses due to brucellosis induced abortions.

The technique does not have geographical limitations which can be defined in general terms. However, regional limitations may occur. For example, an owner interview survey developed successfully in Zambia was not considered appropriate in an area of neighboring Mocambique, due principally to the absence of approximately 70% of the men for eight months of the year in the South African mines (Perry, 1982). Needless to say, security problems can also limit the range of this and any other survey technique.

Design and technique.

Design and technique will vary consideralby from country to country, and will depend on the objectives of the survey. Some points to be considered are discussed below:

i. Evaluation of results: The procedure for data analysis should be designed before the survey is actually carried out, this will have a practical bearing on survey design. The preparation of a concise written questionnaire and a tabulated results sheet is helpful.

ii. Standardization of interview technique. This is critical if differences observed are to be attributed to real variation and not variation in interview technique. This can be done by the use of one interrogator, as recently described in Sudan and Zambia (McCauley et al., 1983b, Perry et al., in press). The disadvantage of this technique is that the survey time is extended, and if larger regions are being covered, the interrogator may require fluency in more than one language.

To ensure standardization, a written prepared format is important. However, this must be reconciled with the need to minimize the writing of each response, and to make the interview as informal as possible.

iii. Interview time period. Interviews cannot be rushed if they are to be effective. Custom often requires considerable time to be spent on introductions, during which it is important for the interrogator to explain the reason for the questions, and gain the confidence of the farmer. In the Zambia survey, a period of approximately 90 minutes was taken for each interview, while in Sudan the time was often an entire day.

With entirely pastoral cultures, time periods required vary with the procedure adopted. Sollod and Knight (1983) reported that the length of interviews in a predominantly owner interview survey in Niger depended on the site chosen. At a well, interviews lasted for several minutes, but in the camps they lasted for several hours. Pastoral systems present an unusual logistics problem when compared with sedentary agricultural systems, and the approach to this has recently received detailed attention (Sollod and Knight, 1983).

iv. Choice of interrogator. In most areas within the experience of the authors, livestock owners are suspicious of visitors asking questions, particularly if they are connected with government organizations. In many places the veterinary assistant or his equivalent is well known to them, but this is by no means universal. Even if they are, this can be a negative attribute if they also hold government functions such as that of tax collector (Nuru and Dennis, 1976; Grindle, 1981). The interview should be done by an independent person, preferably a veterinary assistant or equivalent, indigenous to the region, and fluent in local language if appropriate, but certainly never a foreigner. Even the presence of a foreigner during the interview can seriously bias results in many countries.

v. Order of questions. While strangers asking questions are suspect, those asking questions about livestock numbers are doubly suspect! These numbers are very important for productivity and economics data. Perry et al. (in press) kept this question until the end of the interview, once the confidence of the farmer was secured. An additional technique used by McCauley et al. (1983b) to avoid this bias was to include in the assessment of cattle numbers an estimate given by a neighbor, a method they considered to be most effective in Sudan. The competitive nature of society is common to both the developed and the developing world, and neighbors everywhere have a fairly accurate knowledge of the numbers of cattle owned by each other.

vi. Selection of interviewees. Population sampling for surveys is extensively covered in the literature, and includes the applications to veterinary epidemiology (Leech, 1971a; 1971b; Leech and Sellers, 1979). In animal health survey in developing countries, the practical samplings options available are usually limited. Accurate list frames of livestock owners are rarely available, and population distribution is rarely uniform, influenced by factors such as tsetse fly distribution for example.

If cross-sectional survey techniques are applied, the population to be sampled should be as specific as possible for the economic determinants of the study. Also, most disease surveys require stratification of the population, and it is important to carefully define these strata before the survey in order that there are sufficient numbers to meet the objectives of the survey. While attempts at randomness have been made in some studies, the defence of a strictly random sampling procedure may be difficult to justify due to absolute lack of data (Broadbent, 1979). This should be recognized in the study design, and consideration given to the performance of as large a number of quality interviews as possible under the geographical and cultural restraints.

Other factors in the selection of interviewees include the choice of the individual with the knowledge and responsibility for the animals in question. For cattle, this is usually a man, but for small ruminants is often the women (Mares, 1954). This choice will influence the confidence in results (see later).

vii. Period of recall. Surveys which ask "Have you ever seen this disease," or "How many calves do you usually have each year" are of extremely limited value, and have little role to play in economic studies. Surveys should cover a specific period of time, and all data collected should relate to that same time. The Sudan survey used the year immediately prior to the start of the survey which was timed to follow the period of highest seasonal incidence of bovine schistosomiasis. This allows greated confidence to be put in numerical data volunteered, and also allows seasonal variations to be considered. However, a major limitation of this procedure is that short-term changes in events may influence the survey, and thus control programmes for years to come. An example is the high adult cattle mortality seen in one of the surveyed districts in Zambia due to severe outbreaks of haemorrhagic septicaemia and heartwater. Validation by modelling (see later) can assist in the identification of these anomalies, providing the data used to develop the model are generated independently.

Accuracy and validity

Having defined the role of the owner interview survey, and carefully designed and executed the study, it is disheartening to say the least to hear the criticism "well, what use is the livestock owner's information and opinion, anyway?" The common criticism is twofold: recall of dates and numbers is inaccurate and diagnostic ability is poor.

In most developed countries, a pecuniary society exists in which the unit of currency is the focal point. Ask a person about his investments, stocks and shares, and he will relate with reasonable accuracy his position. In developing countries, this pecuniary society exists only in the cities and large towns. In the country, the economy often revolves around livestock, with cattle representing status, investment and cash. In a corresponding manner, therefore, the owner has an accurate knowledge of his own "bank balance," and the factors affecting it. This argument identifies one key point in the survey design: the target person to be interviewed should if feasible be the head of the family or group owning the livestock. In many regions of Africa, including Mocambique, Sudan, and Zambia, this person is a man, indicating why the owner interview technique was not appropriate for certain regions of Mocambique. In a few instances in the Sudan survey, the interviewee was a herdsman. The authors placed equal confidence in his observations due to his longstanding coexistence with the cattle.

The accuracy of owner's diagnoses does vary considerably from region to region, and survey designers should take this into account. In general accuracy is greater in pastoral societies than in sedentary societies. The Oromo peoples of southern Ethiopia for example have an acute diagnostic ability, and a common usage of language referring to animal disease which is not found in English (Perry, personal observation). Schwabe and

Kuojok (1981) recorded detailed anatomical, pathological and epidemiological knowledge of Dinka cattle owners in Sudan.

There have been very few attempts to validify results from owner interview surveys, except for the general elections that follow the opinion polls! The opportunity arose in Zambia, where the results of an owner interview survey were compared with data from a small number of sentinel herds within the same districts, and with herd models (Perry et al., 1983).

With the small numbers of sentinel herds used in the comparison (13), direct comparisons were only applied to the proportional data, such as the seasonality of calving, and seasonal variation in mortality figures.

While calving was seen to occur all year round, 70% (owner interview survey) to 79% (sentinel herd data) occurred during the months of June to November. Mortality rates were also comparable, particularly with calves. As the two sets of data were not collected during the same year, this indicates a high degree of conformity in the trend pattern, which is of use in the differentiation of short term effects mentioned earlier.

Comparison with model data allowed two assessments. One was the degree of conformity with an ideal model situation, to determine any gross inconsistency in the dynamics. The second was a comparison between models of the questionnaire data and the sentinel herd data to assess the repeatablity of any inconsistencies in the dynamics (Matthewman and Perry, submitted).

CONCLUSIONS

Surveillance of animal health and production is an essential component of animal health programs in developing countries, both for epidemic infectious disease and less dramatic endemic entities for assessment of economic impact. Prevalence data, although valuable, does not supply data pertinent to the calculation of cost-benefit relationships. Owner interview surveys can generate this data if carefully planned and executed, and if they form part of a larger animal health program. Further validation studies of such surveys are indicated, to augment confidence in their use by governments and other agencies.

REFERENCES

Biggs, S.D. (1980). On-farm research in an integrated agricultural technology development system: case study of triticale for the Himalayan hills. Agriculture Administration, 7:133-145.

Broadbent, D.W. (1979). Field collection of animal disease data in developing countries. World Animal Review, No. 29:38-42.

Domenech, J., Lucet, Ph., and Coudert, M. (1982). La brucellose bovine en Afrique centrale: V. Description d'une methode d'enquete simplifice. Revue D'Elevage et de Medecine Veterinaire des Pays Tropicaux, 35:125-129.

Grindle, R.J. (1981). Economic losses from east coast fever, with special reference to Malawi and Tanzania. Paper presented at International Conference on Advances in the Control of Theileriosis, ILRAD Nairobi.

Leech, F.B. (1971a). A critique of the methods and results of the British national surveys of disease in farm animals. I. Discussion of the Surveys. British Veterinary Journal, 127:511-522.

Leech, F.B. (1971b). A critique of the methods and results of the British national surveys of disease in farm animals. II. Some general remarks on population surveys of farm animal disease. British Veterinary Journal, 127:587-592.

Leech, F.B. and Sellers, K.C. (1979). Statistical Epidemiology in Veterinary Science. Charles Griffin and Company Ltd. London. 158 pp.

McCauley, E.H., Majid, A.A., Tayeb, A. and Bushara, H.O. (1983a). Clinical diagnosis of schistosomiasis in Sudanese cattle. Tropical Animal Health and Production, 15:129-136.

McCauley, E.H., Tayeb, A. and Majid, A.A. (1983b). Owner survey of schistosomiasis mortality in Sudanese cattle. Tropical Animal Health and Production, 15:227-233.

Mares, R.G. (1954). Animal husbandry, animal industry and animal disease in the Somaliland Protectorate. British Veterinary Journal, 411-423.

Matthewman, R.W. and Perry, B.D. (submitted). Measuring the benefits of disease control: the relationship between herd structure and herd productivity. Tropical Animal Health and Production.

Nuru, S. and Dennis, S.M. (1976). Abortion and reproductive performance of cattle in northern Nigeria: a questionnaire survey. Tropical Animal Health and Production, 8:213-219.

Perry, B.D. (1982). Animal disease control, Mozambique. Food and Agriculture Organization Consultant Report AG:GCP/MOZ/018/SWE, pp. 6, 22.

Perry, B.D., Matthewman, R.W., Eicher, E. and Snacken (1983). An evaluation of the efficacy of a questionnaire survey by comparison with data from sentinel herds. Proceedings of the Third International Symposium on Veterinary Epidemiology and Economics. Veterinary Medicine Publishing Company, Edwardsville, Kansas, p. 667.

Perry, B.D., Mwanaumo, B., Schels, H.F., Eicher, E. and Zaman, M.R. (in press). A study of health and productivity of traditionally managed cattle in Zambia. Preventive Veterinary Medicine.

Schwabe, C.W. and Kuojok, I.M. (1981). Practices and beliefs of the traditional Dinka healer in relation to provision of modern medical and veterinary services for the Southern Sudan. Human Organization, 40:231-237.

Sollod, A.E. and Knight, J.A. (1983). Veterinary anthropology: a herd health study in central Niger. Proceedings of the Third International Symposium in Veterinary Epidemiology and Economics, Veterinary Medicine Publishing Company, Edwardsville, Kansas, pp. 482-486.

THE USE AND POTENTIAL OF VIEWDATA FOR THE VETERINARY PROFESSION

E. M. VARLEY*

VIEWDATA derived originally from an idea by Sam Fedida who was investigating for the British Post Office the potential of a picture-telephone service called Viewphone. However the British Post Office were unable to register the name 'viewdata' as a trademark and adopted the name 'Prestel' instead. Viewdata is now accepted here and in most parts of the world as a generic term. Videotex is the alternative and generally recognised term in Europe and Canada. Video text is occasionally and wrongly used as an alternative and has now been registered as a trade-name for specific services.

Teletex is the generic term for information services which are similar to viewdata in that they use adapted television sets to display pages of text and graphics, but is distinguished by being broadcast only (non-interactive) and therefore limited in scope.

Teletext is a text communication standard for communicating word processors and similar terminals combining the facilities of office typewriters and text editing.

PRESTEL

This paper will only consider the PRESTEL system now operated by British Telecom and at present the only interactive viewdata system available in this country. An adapted television with, at its simplest, a numeric keypad, is used as a terminal to receive information held centrally on computers (owned by British Telecom) via the telephone line. Each user is individually identified by a unique number - usually a dedicated telephone line number - and is registered to access with a password a minimum of 2 computers. This enables maintenance and scheduled down time to occur without interrupting the service to customers. Information on the central databases is provided by Information Providers (IPs) who pay British Telecom for the service. Current charges are shown in Table 1.

*Veterinary Officer, ADAS Unit, NAC Stoneleigh, Kenilworth, Warwickshire CV8 2LG

Table 1. Information Providers (IP) Charges - Summary December 1983

3 digit entry point rental	£6500 pa
This charge includes	
a) facility to enter and amend information and to retrieve response frames	
b) 100 frames	
c) capacity to store 10 completed response frames	
d) editing training for 2 staff (2 day residential seminar)	
e) copy of IP editing manual	
f) annual print-out of frames in use (if required)	
g) bulk update facilities (if required)	
Additional frame rental	
Each unit of 100 frames	£500 pa
Mailbox frames (for each format)	£ 20 pa
Closed User Group facility (bulk discount terms available)	£320 pa
Sub - IP facility	
This allows a sub-IP to perform his own editing within a discrete part of the main IP's database	£320 pa
Editing charge Main IP's	Nil
Sub-IP's Mon-Fri 8am-6pm	8p per minute
All other times	8p per 4 minutes
Response frame collection	4p per frame
Factoring charge	8%
% frame revenue retained by BT/Prestel	

The type of information currently held is wide ranging - such as timetables, guides, stock and commodity prices; a message sending facility is available; teleshopping is possible; software for personal or desktop computers can be distributed. Information is displayed in pages of either text or graphics (or both).

Prestel is available as a mass service and can be used by private individuals at home, businesses or in public places such as libraries, airports, post offices. The only qualifications required for users are the ability to pay for both equipment and service, and a good memory for your user number (10 digits) and a password (4 digits). Access to private services is available through closed user group (CUG) using an additional registered password under the control of the IP operating the CUG. Private viewdata (CUGs) services offer security, restricted access, and beneficial tariffs in return for high volume usage.

Four classes of service are available:-

Information retrieval whereby users seek and find information for display on their terminals.
Message service whereby users can communicate to other specified users specific pages which may be information, or transactional, such as a bank account transfer instruction.
Computation involves data processing, under the user's control, at the viewdata centre the programs required being stored on the database and executed on a computer in the system.
Software distribution, sometimes called telesoftware, whereby users specify the software item they wish to retrieve.

Viewdata is only another medium for communications and information retrieval which may hold some advantages over the telephone. The alternatives for information retrieval are primarily printed material, the telephone and conventional computer systems; for sending/receiving messages, the telephone, postman-delivered mail, telex, communicating word processors/teletex devices, and computer-based message services; for computation, desk top calculators, micro and mini-computers or time-sharing bureaux services; for software distribution, the sale of prerecorded cassette tapes or floppy discs.

Users of Prestel pay normal telephone charges incurred on connection to the computer, a standing charge and depending on the time of day, a time based charge. A page charge may be incurred when a page is accessed but the initial menu will tell the user what this is before he keys a chargeable page. The IP fixes the price of a page and this is automatically displayed at the top right corner of the screen. The system holds a billing account for each user and debits this according to usage. A quarterly bill is sent which is separate from the telephone bill.

USE OF PRESTEL BY THE VETERINARY PROFESSION

As already stated Prestel is a communications and information retrieval medium. There are different categories of information provider and users within and associated with the profession. For example:

Statutory and corporate bodies - RCVS and BVA
Veterinary practitioners
Pharmaceutical companies
State Veterinary Service of ADAS, and MAFF
Veterinary wholesale suppliers of drugs and equipment
Farmers
Companion animal owners
University veterinary schools.

Each of these groups will perceive different needs to be met and will use Prestel in differing ways. The advantage of a computer based information retrieval system is that it satisfies two fundamental needs of users:-

- the need to identify quickly what information is available on a subject and where to find it (bibliographic information)
- the need to have ready access to information which frequently changes and where speed of access and up-to-date accuracy are of prime importance (active information).

Of the groups listed, the BVA did participate in a Prestel experiment in 1982 sponsored by Hoechst Animal Health, ICI and the Wellcome Foundation who provided 100 pages and adaptors for use by participating practices. All the information was restricted through the closed user group facility. This experiment will be mentioned later in the paper.

An unknown number of practitioners may be Prestel users. Three pharmaceutical companies are IPs; namely ICI, Merck, Sharp and Dohme (Baric)* and Wellcome Foundation (Baric). The latter two are sub-IPs under the Baric umbrella. ICI, and MSD provide limited product information and some advice on anthelmintic usage and grazing systems to control parasites, whilst Wellcome provide a CUG for the medical and veterinary professions. The State Veterinary Service of ADAS currently provides about 100 pages on cattle, pig and chicken diseases and is expanding this database to include sheep diseases and disease forecasts. In addition veterinary input is supplied to pages jointly compiled with other services of ADAS. Other information is provided on notifiable diseases of horses and farm animals, rabies, SVD precautions and currently Newcastle Disease precautions. There are embryonic ideas for a monthly disease calendar, drug information, export and import, meat, disease prevention, animal welfare and zoonoses. The whole ADAS database is currently under review and information is much more likely to be provided in enterprise form in the near future such as illustrated by table 2. Additionally species information may not describe specific individual diseases but syndromes e.g. respiratory disease in calves or egg production depression, and stunting syndrome in poultry.

Farmers are an increasing body of Prestel users with approximately 700+ registrations.

The number of companion animal owners is unknown but likely to be very small.

No university veterinary schools are known to the author as Prestel users.

The BVA Prestel Experiment

The BVA recognised the potential of viewdata as a means for more effective and rapid communication with its members. (Not all veterinarians are BVA members - author's comment).

The topics covered included:-

BVA news and information e.g. publications, agreed and recommended fees, disease control schemes, veterinary defence and welfare legislation.
Veterinary investigation service reports.
Courses, meetings and congresses.
Drug and equipment information.
Disease forecasts cross referenced to existing MAFF and ADAS information.
In addition the sponsoring companies developed their own databases integrated into the BVA information service to provide direct links between one information source and another.

The BVA experiment lasted about 9 months and at the time was beset by a number of technical problems within Prestel itself and other administrative hitches. The trial was early in the development of Prestel and is worth repeating.

*Baric Computer Services Ltd. is a major systems provider for Prestel IP's.

ADAS

Table 2. Livestock Index
e.g. PIGS

1. Physical performance standards	(i) Breeding stock (ii) Rearing stock (iii) Finishing stock
2. Breeding	(i) Performance/Progeny Testing (ii) Undesirable Characteristics (iii) Breeds (iv) Cross breeding (v) Herd replacements (vi) Mating management/AI
3. Feeding	(i) Breeding stock (ii) Rearing stock (iii) Finishing stock (iv) Individual feed values (v) Feed formulation
4. Environmental requirements (Housed or Grazed)	(i) Breeding stock (ii) Rearing stock (iii) Finishing stock
5. Housing layouts and cost	(i) Breeding stock (ii) Rearing stock (iii) Finishing stock
6. Health	(i) Diseases of breeding stock (ii) Diseases of rearing stock (iii) Diseases of finishing stock (iv) Preventive medicine
7. Management systems	(i) Breeding stock (ii) Rearing stock (iii) Finishing stock
8. Financial	(i) Budgets (ii) Recording scheme results (iii) Product marketing (iv) Market outlook
9. Index/Booklets	

THE FUTURE POTENTIAL OF PRESTEL TO THE VETERINARY PROFESSION

It must be admitted that at present there are relatively few users of Prestel in or immediately associated with the veterinary profession. However the viewdata medium is very new, Prestel itself only having been publicly available since May 1979. At that time it was the world's first viewdata system. Like many things new the chicken and the egg syndrome exists in Prestel. More people will use the system when more facilities and information is provided, but IPs are reluctant to invest in this provision until more users are registered. There has been a slower than expected take off for a combination of reasons: the recession, competition for money offered by video-recorders and microcomputers, the dramatic growth in ownership of Teletext sets (over 1 million), difficulty in getting public to understand what viewdata is, the lack of suitable, in-depth information, and the problem of persuading people to pay for information which they have previously received apparently free - or for which they have not been aware of a need.

In March 1984 there were 158 IPs, with over 900 sub-IPs, 316,000 frames in use, and 14.7 million frame accesses. Although much of the veterinary information that could be provided on a database would be bibliographic, there is certainly some which would be active and require frequent updating. In the author's experience the crucial area in determining the success of an IP's database is its management. It appears to be essential to have a dedicated operator and firmware to handle the operation and especially the routeing between frames, and keeping information up-to-date. In the agricultural field a step has already been taken in the South West to provide a pilot project in total agricultural database management called Prestel/Farmlink. It is already possible by gentleman's agreement to cross reference the pages of one IP to another to mutual benefit. The advantage of complete database managed by an agent means that all the indices and routeings are done formally on your behalf.

In the veterinary field the first step is to provide a comprehensive database, and if possible to appoint one agent to manage the whole. As much of the information may be of a commercial nature, or in other ways not appropriate to public consumption e.g. POM product information, then this can be accessed through the closed user group facility. Then only veterinarians or appropriate pharmaceutical companies, statutory bodies, universities could gain access. The author would suggest that the BVA might be the appropriate body to manage a veterinary database possibly with some commercial sponsorship.

Bibliographic information could be provided by BVA; services to members, disease control schemes e.g. BVA/KC Hip Dysplasia Scheme, publications, fees. Active information could be job opportunities, news frames, details of congresses, courses and meetings.

RCVS could provide bibliographic information about legislation, professional conduct, further education, and parliamentary matters.

Pharmaceutical companies already have to provide datasheets on their products and this is published by the Association for British Pharmaceutical Industry and posted to veterinarians. This could be provided through viewdata. Equally drug catalogues could be drawn up listing across the board products that are suitable for treating particular conditions. Special warnings about products could be disseminated rapidly and news about new products. In return practitioners should be able to report any adverse reactions to drugs via the medium.

Veterinary wholesalers and equipment suppliers could catalogue and accept orders and bill their clients through Prestel. Practitioners would know immediately if the products they require were in stock and if not could obtain them elsewhere if urgent.

State Veterinary Service involvement in Prestel has already been mentioned and will continue to be closely allied to the agricultural database. An area of active information which could usefully be included would be VI Centre reports, locally and nationally, which may be useful to indicate disease trends or inform about newly diagnosed problems.

In the future the profession should make good use of closed user groups for distributing information. But the interactive capabilities of Prestel should also be used. ICI for example already have response frames to allow Dairymaid herd recording information to be input and this considerably speeds up the analysis and turnround time.

Mailbox is an electronic mail service available to users to send messages to another user, at less cost than letter postage. It is secure, messages can be stored or printed, and can be sent at anytime. The recipient does not have to be in his office at the time, unlike the telephone.

Telex facility is becoming available to allow any Prestel user access to the international telex network. Hard copies are available each end which allows reference back to the original without the possibility of errors which can occur in transcribing phone messages.

Gateway allows Prestel to be linked to other computers. Users will notice no difference when switched from one computer to another. However it means that many organisations may be able to attach their own computer to Prestel. ADAS is currently exploring this possibility using their Prime minicomputers. Gateway will allow much more data collection from scattered terminals into a central point where it is processed and rapidly made available again.

Private viewdata systems look and behave just like Prestel but run on a private computer. This is possibly the area of greatest potential because it combines information collection and retrieval with data processing. The system is under an organisation's or individual's control. Powerful facilities can be provided e.g. access to other computer files and programs, networking. It allows for a more sophisticated security system.

International access is already possible. We should not lose the opportunity to use this rapidly developing medium. France has already developed an electronic telephone directory with viewdata terminals replacing existing books. In addition to acting as a directory the terminals allow access to the range of viewdata services.

In Manitoba an electronic publishing company launched an agricultural service in 1981 and the service is now expanding throughout Canada and the USA. The company employs 30 people to develop, market and operate the system.

In Finland, agricultural advisers have portable terminals which connect on the farm to a central computer at the Agricultural Data Processing Centre in Helsinki. Individual farmers can acquire terminals and make direct use of the programs.

In New Zealand the first commercial users of a viewdata system will be veterinarians. The information has been provided by the Bureau of Primary Information.

In the UK Prestel will hopefully be able to provide high resolution graphics, animation and audio. The veterinary profession should not lose the opportunity to be involved with this useful electronic medium.

PRELIMINARY INVESTIGATION OF COMPUTERS AS AN AID TO TRACING THE SPREAD OF EPIDEMIC DISEASE

A J ELLIOTT*

Wilesmith and Richards (1982) suggested that a computerised system similar to the READI system used in the USA should be considered for use in emergency disease control centres in this country. Following the introduction of a microcomputer into Leeds Animal Health Centre in 1983, it was decided to see if we could set up a simple system to assist notifiable disease tracing for Foot and Mouth Disease (FMD) and Swine Vesicular Disease (SVD). An outbreak or epidemic of these diseases receives our highest priority involving a lot of staff and visits, and any method of saving time should be investigated. Normally, in notifiable disease outbreaks, a separate disease centre is established with staff from Divisional Offices.

A small working group was formed whose main term of reference was to review our existing system to see whether computers can improve the information provided to Veterinary Staff, as well as accelerating the production of information and make it more widely available. If successful, the system would then be extended to other diseases. Within the Veterinary Service of MAFF, there already exists a well-tested tracing system for FMD. The administrative side of this rests on a card index file maintained at the disease centre which contains details of all premises involved in the outbreak. Information from the system is used to deploy field staff efficiently on tracing, patrol and infected premises duties.

THE SOFTWARE

Our computer arrived with a commercially available database package** which we have adapted for the project. The package has a wide range of data input, manipulation, and retrieval facilities including the facility to transfer data between files. Our fundamental unit is the premises record, and there will be one record for every premises, whatever its involvement in an outbreak. Each record is divided into 3 sections:

Header

The header contains static information about the premises including name and address of owner and premises, map reference, type of enterprise, stock

*Veterinary Officer, MAFF, Animal Health Centre, Quarry Dene, Weetwood Lane, Leeds, LS16 8HQ.

**DELTA (TM), Compsoft

numbers, current restriction status and a flag to indicate whether a tracing report form (TRF) or Milk Marketing Board (MMB) listing is required.

Visit section

The visit section of the record contains data about visits to the premises such as reason for visit, date, associated market or infected premises (IP), Officer visiting, samples taken and result. A major feature of the package is that it allows an unlimited number of sub-records in this section so that multiple visits or reasons for visiting a premises, can all be recorded under the one header for that premises.

Infected premises section

If the premises becomes an IP at any stage, this section allows recording of IP specific data such as its National Disease Reference number, date confirmed, dates of valuation, slaughter and disinfection, and date restrictions lifted. It is possible for a premises to become an IP more than once in an epidemic and again, the package allows for more than one IP record should this become necessary.

A separate database "HERDS" containing records of all cattle premises in Yorkshire, is currently maintained on our computer and we will soon be adding sheep and pig only premises. Individual Header records can be transferred from this to the tracing database and this should save some data input time.

The format of the tracing records was constructed from a careful consideration of the input data available and the output reports required.

SOURCES OF INPUT DATA

The main sources of information for entry into the database are:

- Reports of disease from farmers and veterinarians.

- Lists of vendors and purchasers from a market which is being traced.

- Lists of contiguous and dangerous contact premises supplied by investigating officers on IPs.

- Lists of premises within patrol areas, taken from the HERDS database.

- Tracing report forms (TRFs) returned by visiting officers.

Most of the data has to be typed in manually but a certain amount of it can be transferred directly from the HERDS database.

OUTPUT REPORTS

The printed outputs which are available from the system are:

1. A master index of all premises involved in the current outbreak. This is equivalent to the clerical card index.

2. Master market tracing lists based on individual markets and dates.

This information is essential in helping senior management to decide on the extent of infected area restrictions.

3. Tracing report forms for handing to officers making visits to premises. These forms contain basic premises data, map reference and reason for visit, for the information of the officer concerned. He completes the form with visit information for later input to the computer.

4. Progress lists showing the current state of all premises where there is continuing action.

5. Daily list of addresses of new IPs and dangerous contact premises to supply to the MMB and AI Centres in the area as required by an existing Code of Practice.

These outputs are required by the existing tracing system. Other outputs which are now available are:

6. Officer-in-charge's daily list. Similar to the progress list already mentioned, this list would give much more information about each premises involved. In large outbreaks, the list could be partitioned into, for instance, lists of visits due that day, lists of overdue visits, and premises where laboratory results were outstanding. This useful management information could be printed immediately on request.

7. Daily lists of tracings sent to, or received from, other Centres or Divisional Offices, to allow progress chasing.

8. Daily IP progress reports.

9. Tracing lists of all premises associated with a particular IP.

10. When all action on an IP has been completed, a final report can be printed which includes details of all associated tracings.

11. Lists of actionable premises divided according to livestock hauliers involved. This information may help to identify infected vehicles.

12. List of all premises within a given radius of an IP, selected by map reference, to allow patrol visits to be arranged. This information is extracted from the HERDS database and can be transferred directly to the tracing system.

13. Similarly, address labels can be printed for all premises within an 8 km radius of an IP. This allows a standard letter to be posted immediately to neighbouring farmers informing them of the imposition of emergency restrictions in the area. This method would improve existing methods of publicising an outbreak.

All this information can be produced using the selection, sorting and reporting options of the database package. The record format was designed in such a way as to allow the selective production of the specified reports.

ADVANTAGES OF A COMPUTERISED TRACING SYSTEM

The potential benefits of a computerised over a manual system are:

1. Information is kept readily accessible on a local database.

2. The speed of response is much improved.

3. Clerical time spent selecting information and drafting and typing reports is greatly reduced.

4. The amount of information available to centre management and tracing staff is increased.

5. The system fits the existing tracing system so that few changes in approach are required.

6. The potential exists for rapid electronic data transfer between local disease centres and Regional and National Offices.

7. The system is portable, requiring a minimum configuration of a microcomputer, floppy disk unit and printer, for installation in the disease centre.

POTENTIAL PROBLEMS

Two main problems are envisaged. As with any computerised information handling system, the quality of output depends on the quality of input. In a tracing exercise, a proportion of the input data may be incorrect or incomplete and there is a strong possibility that duplicate records for the same premises could be produced. A number of facilities are built into the system for manual intervention. New data arriving can be pre-checked against earlier printouts to prevent the entry of duplicate records and this should not take longer than existing methods. However, the greater volume of data maintained on the database will mean that extra time spent inputting data is unavoidable.

The other main problem is that of staff training and familiarity with the system. A disease centre can be set up at 24 hours notice and requires a staff familiar with the system who can implement it straight away. If a computerised system were to be adopted, staff would need prior training and experience of using computers. However, the database package is quite "user friendly" and staff should have no great difficulty learning to use it.

CONCLUSIONS

At the time of writing, we are still in the early stages of setting up the database programs on the computer. Once established, a test run will be carried out using sample data, to highlight any problems. The sample data will use records from a 1980 series of SVD outbreaks in Yorkshire as a model and we hope that the results of the trial will be available in time for the Conference.

REFERENCE

Wilesmith, J. W. and Richards, M. S. (1982). Report on the Third International Symposium on Veterinary Epidemiology and Economics, Virginia, USA. September 1982. ADAS Publication 31p.

THE POTENTIAL APPLICATION OF COMPUTERISED MAPPING SYSTEMS

P.A. WILLIAMS*

Maps have always been a very useful medium for illustrating the distribution of livestock populations, disease outbreaks etc. A table can give exact figures, for example of outbreaks by county, by year, but the visual impact of a map is far greater. The problem with producing such a map is that someone has to sift through an assorted list of Ordnance Survey (OS) grid reference numbers and then plot them laboriously by hand.

Computers have already helped marginally in this task. Once a database has been established, selection of records by various criteria can be undertaken and listed in grid reference order for ease of plotting. For instance, records can be selected by year so that the first year can be plotted with one symbol or colour before changing to the year represented by the next block of numbers.

Holdings may be identified for mapping purposes by either County Parish Holding number (CPH) or OS numbers. CPH numbers are useful for agricultural census data which are identified in this way (see CAMAP) but have the disadvantage that one CPH number can cover more than one premises not necessarily located in the same parish or even county. Also many of the smallholdings on which disease has been recorded are too small to appear in the census. Therefore for animal disease purposes it is preferable to have a fairly accurate OS grid reference for the location of an infected premises.

One of the uses we have made of the power of computers is a system to locate points within a given radius, which we call the 'Circle Procedure'. The veterinary service has several sets of data held on a computer which handles the data using NOMAD - A Data Base Management System package. Three of these data sets: Markets, Slaughterhouses and Large Livestock Units [a LLU is defined as a holding with more than 500 cattle, 2000 sheep or 2000 pigs] hold information on location, identification and various relevant items. In the event of a disease outbreak it is possible to obtain a list of the appropriate premises within any defined radius, the list giving the OS numbers and distance in kilometres of the said premises form the central point. On retrieval, items of interest such as problems of carcase disposal on LLU's and slaughterhouse throughput capacity, can assist in drawing up control strategy.

It is necessary for this procedure for all map references to be stored in a standard format of 8 consecutive digits, i.e. 2 alpha and 6 numeric characters. Needless to say, the system is only as good as the data input and on data validation it is not unusual to find livestock premises apparently situated in the North Sea.

None of this takes away the need for manual plotting of co-ordinates onto

*Epidemiology Unit, Central Veterinary Laboratory, Weybridge, Surrey

an existing outline map, so the next stage is the use of specific cartographic packages. SYMAP was an early package developed at Harvard University. However I believe that this just produces line-pinter output, which seriously limits its ability to produce high quality graphics.

CAMAP, a package developed by the University of Edinburgh, Department of Geography, has potential applications within MAFF for handling agricultural census data as it is set up to process data on a parish basis. It uses a variety of symbols and shading techniques to represent either types of enterprise, land clissification etc. or density as for example in the percentage of full time holdings with dairy cattle.

However the package which I have been investigating in particular is called GIMMS, again developed in Edinburgh this time by Thomas Waugh. It has a very wide range of cartographic options and can produce medium to high quality maps according to the quality of the plotter available for output. It not only produces maps but also graphs and bar and pie charts.

Data handling is divided into topographic and thematic data. The topographic section handles point and outline co-ordinates. Once these have been fed into the system the same outlines and points can be redrawn time and again. Areas can be outlined within a map, e.g. counties, and actual points, e.g. disease outbreaks can be accurately placed on the map according to a predefined grid.

The thematic data consist of the characteristics of the variable under consideration e.g. the number of pigs on a holding, the herd type, the date of disease outbreak etc. GIMMS ties the two sets of data together and allows use of selection criteria so the map can be redrawn in various ways using the same co-ordinates but using different thematic aspects. One could first plot all pig holdings in an area, then redraw having selected only weaner-breeders with a herd size of 200-400. The package allows simple calculations, such that population densities can be worked out for given areas. For more complex calculations the data may be first manipulated with a statistical package, and then read into the system. Reading both topographical and thematic data from existing computer files obviates the necessity to re-enter the required data manually.

The system allows for an enormous range of symbols and lettering, available in a variety of sizes which can in fact be printed in a size proportional to the variable in question e.g. herd size. Colours are also available and pie and bar charts can be plotted onto the map itself or adjacent to it. Output can be to a VDU screen or to a plotter. By using a graphics screen, the map can be built up and altered to suit the user before being output to a plotter.

This is but a brief overview of one cartographic package. Packages of this sort have great potential in the veterinary field for examining our vast wealth of collected data in a new light. The ability to juggle data and produce clear graphic displays may well assist in identifying patterns of disease not clearly visible from the morass of tabulated figures.

REFERENCES

Dougenik, J.A. & Sheehan, D.E. SYMAP Users Reference Manual. Harvard University School of Graduate Design, 48 Quincy Street, Cambridge Massachusetts 02138

Hotson, J & Kirby A.S. CAMAP Programs Manual August 1978. Report No.26 Program Library Unit, University of Edinburgh, 18 Buccleuch Place Edinburgh

NOMAD 2 Reference Manual January 1983. D & B Computing Services 187 Danbury Road, Wilton Connecticut 06897

Waugh, T.C. (1980) IN Taylor D.R.F., Editor "The Computer in Contemporary Cartography", pp219-234 John Wiley & Sons Ltd

Waugh, T.C., GIMMS Reference Manual Release/Edition 4·5 1983. Keir Street, Edinburgh EH3 9EU

ECONOMICS OF HEALTH

ASSESSING THE BENEFITS AND COSTS OF A COMPUTERISED INFORMATION SYSTEM IN DAIRY HERD MANAGEMENT

H. J. PHARO,* R. J. ESSLEMONT * and S. N. H. PUTT *

Computerised dairy information systems have been under development at the University of Reading since 1972. They have progressed from mail-in mail-out bureau operations on mainframe computers (Esslemont & Ellis, 1975) to local bureau and on-farm services based on microcomputers (Stephens *et al*, 1981).

It is the local bureau service that is of particular interest to veterinary practices involved in the provision of planned animal health and production services to the dairy farms of their clients.

There is however little information available on the costs and benefits of operating these systems from a veterinary practice. This paper describes a method of evaluating their costs and benefits from the point of view of both the veterinary practice and the farmer client.

BENEFITS AND COSTS FROM THE POINT OF VIEW OF THE FARMER

Benefits

It is difficult to consider the effect of computerisation on the productivity of a dairy herd on an isolated basis. The adoption of a computerised recording system on a dairy farm normally forms one component of a package of improved management practices instituted by the manager who wishes to improve the productivity of the herd. The decision to use such a system is usually taken because the farmer wants to have a better understanding of the performance of his dairy herd in order to manage it more efficiently, and therefore there is usually no clear "before" data with which to compare the "after" situation.

A strategy for optimum economic milk production: The basis of profitable milk production is to evolve a strategy that aims at achieving the optimal conditions for economic milk production under the circumstances of a particular farm, and to closely monitor the herd performance in pursuance of this strategy so that it is possible to react quickly when the records show a deviation from the objectives laid down.

Arriving at an optimum strategy for any particular farm is not easy, since the process of economic milk production is governed by a large number of variables, many of which are either unknown or improperly understood. Esslemont (1982) has, however, suggested the following general strategy for achieving optimum economic milk production.

*Veterinary Epidemiology and Economics Research Unit, Department of Agriculture and Horticulture, University of Reading, Earley Gate, Reading RG6 2AT

a) Ensure that the main objective of the herd is milk production.

b) Select the most profitable and practical calving season for the particular farm circumstances.

c) Devise a strategy of fertility management that ensures that cows are served by the right bull during the appropriate service period in order to achieve the above. In pursuance of this, Esslemont suggests the following objectives although these are rarely achieved in practice:

95% of the herd should be served.
95% of cows served should eventually conceive.
    i.e. 90% of cows calving should eventually conceive.
An average interval to first service of 65 days.
80% heat detection during the service period.
A first service conception rate of 57%.
Overall, 55% of all services should result in conception.
1.6 services per conception.
An average calving to conception period of 85 days.
An average calving interval of 365 days.
An average lactation period of 300 days.
An overall culling rate of 15%, one third of which should be for cows failing to conceive.

d) Devise a policy that produces a sufficient number of replacement heifers that are born in the first two months of the calving season so that they can be reared to calve at a sufficient size from 22 to 27 months of age.

The benefits of fertility control: Nearly all dairy farmers are aware of the importance that good fertility management has on the productivity of their herd. Table 1 shows the results of a computer model (Bailie, 1980) which examines the relationships between the interval to first service, and heat detection and conception rates, on the calving to conception interval and culling rate.

Table 1

Effect of interval to first service, heat detection rate and conception rate per service on calving to conception interval and culling rate
(Bailie, 1980)

Interval to 1st service in days	Heat detection rate %					
	50		60		70	
	Conception rate per service%					
	50	60	50	60	50	60
85	107(12)	102(7)	107(8)	102(4)	106(4)	100(2)
75	99(11)	93(6)	98(7)	93(3)	97(3)	90(2)
65	91(9)	85(5)	80(6)	84(3)	88(2)	81(2)

Note: First number is the calving to conception period in days, number in parentheses is the culling rate for cows failing to conceive 190 days after calving.

Using these figures, we can calculate the performance of a one hundred cow dairy herd where the fertility performance is poor. This can be compared with a herd where the farmer has achieved a standard of fertility management approaching that recommended by Esslemont, as shown in Table 2.

Table 2

Fertility performance of a poorly managed compared to a well managed herd

	Poor herd	Good herd
Heat detection rate (%)	50	80
Conception rate (%)	50	57
Average interval to first service (days)	85	65
Results		
Average calving to conception (days)	107	85
Culling rate for failing to conceive (%)	12	5
Percentage of cows conceiving	88	90

As the average calving to conception interval increases beyond 85 days there is an increase in the intercalving interval. James and Esslemont (1979) have shown that each day increase in the intercalving interval costs 132p in terms of lost production less concentrates saved. Using 1984 prices the figure becomes 156p, as shown in Table 3.

Table 3

Effect of a one day increase in intercalving interval from 365 days

16 litres of milk @ 15p per litre	£2.40
less 5.44Kg concs (0.34Kg/litre) @ £155/tonne	84p
	£1.56

But the loss of milk production may be as high as 27 litres (Drew, 1982) which makes the losses even worse (£4.05 -£1.42 = £2.63)

As well as this loss, a cow with a long intercalving interval slips away from the target calving season. In the instance of an autumn calving herd, it has been calculated (James & Esslemont, 1979) that for the worst case, i.e. a cow slipping 7 months to calve on the first of April instead of the first of September, there is a decrease in lactation length of 45 days which costs £84 per cow. This £84 over 7 months is equivalent to 40 pence per day's slip in the calving pattern, taking into account both the lower price for spring milk and the reduced amount of concentrates required for this shorter lactation. When added to the £1.56 calculated for each day of increased calving interval, this becomes £1.96 per day.

In addition, a cow calving out of season or remaining dry for too long a period may be considered uneconomic to keep and be culled as a result. The cost of unnecessary culling can be calculated as the difference between the price realised for a cull cow, say £250, and the purchase price of a replacement heifer, say £500, which is £250. To this we must add the lower profit made by a heifer entering the herd against that made by a mature cow. Esslemont (1983) has estimated this difference at approximately £75. Comparing the culling rate for failure to conceive of 12% against that of 5% recommended by Esslemont we have an unnecessary culling of 7 animals at a total cost of £325 x 7 = £2,275.

Thus an increase in the calving to conception period from 85 to 107 days costs a total of:

21 days x £1.96 per day = £41.14 per cow
= £3,622 for the 88 cows conceiving
plus £2,275 for unnecessary culling of 7 cows
= £5,897

Extra veterinary costs and extra semen costs can be calculated to be about £10 extra for the low fertility herd per cow per year = £1,000, resulting in a total lost profit of £6,897.

This example represents the scale of benefits attainable from better fertility management, but the actual benefits realised obviously depend on the level of fertility performance at the time of introduction of a fertility management scheme. Managing a dairy herd in order to acheive a good level of fertility performance is a complex business, requiring close cooperation between all parties concerned, but in particular between the herdsman and the veterinarian. Esslemont and Baillie (unpublished data) showed that the responsibility for fertility management must, in the final analysis, devolve on the herdsman who needs to be provided with the necessary data and the means to analyse it and act upon it. The use of microcomputer based dairy recording systems can greatly assist him in this task.

There is a dearth of published material on the actual effects of the use of microcomputerised dairy herd recording systems on dairy farms in the U.K. Collick (1982) reported on the performance of 5 herds utilising the DAISY recording system for a period of two and a half years. The main gain was a reduction of the calving to conception interval by 8 days per cow, to 97.5 days in the first year and to 89.4 days in the second year, but there was little change in the culling rate throughout the study period.

Eddy (1981) reported that herds using his DAISY system reduced the intercalving interval by 15.5 days over 4 years, with 12 days being gained from a shorter interval to first service and 3 days from a better conception rate, but there was very little effect from better heat detection after the first service.

The importance of feed planning and control: Dairy farmers typically spend £250 - £330 per cow annually on concentrates, but only £15 - £20 per cow annually on veterinary inputs. If the use of a dairy herd information system allows a farmer to cut 10 days off the intercalving interval, then about £50 per cow will be saved, but if the farmer can cut concentrate feeding by half a ton per cow, he saves £80. Veterinarians, therefore, need to know more on dairy cattle nutrition and economics, to be able to advise farmers on appropriate feeding strategies, and stocking rate, for the higher the stocking rate, the lower the output per cow but the higher the output per hectare (up to 2.5 - 3 cows per hectare).

The use of a computerised feed planning package can give the manager much tighter control over the use of concentrate feeds, resulting in improved margins by more reliance on background forage for production. Experience with users of the Reading bureau has indicated that savings of up to £200 per cow can be achieved in the first year of using a feed planning system, particularly in herds of over 150 cows. Collick (1982) reported that the average margin over concentrates in 5 herds increased from £413/cow to £570/cow over 4 years.

Invisible benefits: Invisible benefits are those which, by their nature, are difficult to cost. In the case of microcomputers on dairy farms, these benefits may include:

a) The satisfaction of knowing the current performance of the herd and the knowledge that an "early warning" system exists which enables the farmer to detect problems before they cause major loss.

b) The achievement of an understanding of computers and their potential.

Benefits actually realised: These results emphasise that the potential improvements in dairy cow fertility can only be made in the presence of good management. This is particularly the case when considering heat detection, which requires a great deal of commitment and vigilance from the herdsmen. Nevertheless, experience with farmers using the DAISY bureau at Reading has shown that the average farmer stands to make at least ten times in increased profits the amount he spends in fees on the bureau. This may not be apparent to start with, because in the first year the cows that conceive earlier than before will be dried off earlier, and will therefore produce less profits, and culling may increase as information becomes available on individual cow performance. This is made up in the second and subsequent years by the increased production per cow from subsequent lactations. When a dairy herd recording system is introduced there is typically a reduction in profit of £15 per cow in the first year, an increased profit of £25 per cow in the second year, and an extra net profit of £55 in the third and subsequent years (Drew, 1982).

Costs

Bureau charges: These can vary quite widely, depending on the frequency and detail of data submission. An example of the sort of fees that farmers are charged for the Reading DAISY bureau is given in Table 4.

Table 4. Charges for the Reading DAISY Bureau

Frequency of records	Type of records	Cost/Cow/Year/£
Monthly	Health + Fertility	1.85
	Health + Fertility + Yield	3.15
	Health + Fertility + Yield + Milk Quality	4.20
Fortnightly	Health + Fertility	3.60
	Health + Fertility + Yield	4.65
	Health + Fertility + Yield + Milk Quality	5.45
Weekly	Health + Fertility	5.70
	Health + Fertility + Yield	6.70
	Health + Fertility + Yield + Milk Quality	8.70

Increased Veterinary Costs: The use of a computerised dairy information system usually results in more involvement of the veterinarian on the farm (Eddy, 1981), increasing veterinary costs by around 20% (20% of £14 = £2.8 per cow per year). The farmer can keep veterinary costs down by having better organisation at routine visits, e.g. by the use of specific action lists.

BENEFITS AND COSTS FROM THE POINT OF VIEW OF THE VETERINARY PRACTICE

Benefits

Fees: Benefits in the form of fee income are the same as the costs to the farmer, as shown in table 4. In addition, there will be extra income resulting from additional time spent on participating farms and from a greater involvement of the veterinarian in the management of the dairy herd arising out of his control of the database. Eddy (personal communication) has found that, on average, this amounts to 20% more on-farm time for the veterinarian. Given an average veterinary bill of around £14 per cow per year, this would represent an increase to £16.80 per cow per year.

Additional Benefits: There are a number of additional benefits to the veterinary practice that are difficult or impossible to cost. These have not been considered in the benefit cost analysis but would include better practice accounting; financial planning through the use of spreadsheets; security in terms of guaranteed regular work, resulting in a more even cash flow, and allowing better planning of practitioner time; increased and broadened expertise in darying gained by working with the database; increased prestige and the attraction of new clients by the practice demonstrating the ability to deal with "leading edge" technology.

Costs

Fixed costs: The cost of the computer hardware will depend on the size of the fixed disc, and this will depend on the size of the bureau to be run. In practical terms, the size of the hardware, and the associated costs, are fixed for any particular bureau operation. The costs shown in the following table are based on the Future Computers FX30/20 microcomputer.

Table 5.

Fixed Costs in Setting up a Microcomputerised Dairy Recording System in a Veterinary Practice

Hardware	Computer (FX30/20)		£3,800	
	Printer (132 column, 150 cps)		800	£4,600
Software	BOS/5 operating system		200	
	Hard disk software		100	
	BOS Autoclerk		100	
	DAISY		1,250	£1,650
Support	Hardware		460/year	
	Software	BOS/5	30/year	
		Hard disk software	15/year	
		BOS Autoclerk	15/year	
		DAISY	850/year	£1,370 per year
Total fixed costs:	Year 1	£7,620		
	Year 2 onwards	£1,370		

Variable Costs: These costs vary with the scale of operation and include the following:

- labour
- paper
- printer ribbons
- floppy disks
- electricity
- telephone
- room rent
- travel
- postage

Based on the DAISY 1 bureau service at Reading, it costs around £10 per 100 cow herd per week to enter data and run weekly reports, i.e. £5.00 per cow per year.

BENEFIT COST ANALYSES

For the purposes of this example, two benefit cost analyses are shown, one from the point of view of the farmer (Table 6), and one from the point of view of the veterinary practice (Table 7).

Farmer's point of view

The benefits to a farmer of a 100 cow herd obviously depend on what his starting position is. For the purposes of these calculations it has been assumed that in the first year the farm will lose £15. per cow, in the second year benefits will be £25. per cow and in the third and subsequent years £55 per cow (see section "Benefits actually realised"). The farmer's costs have been taken as £7.00 per cow per year for bureau fees, plus an increase of 20% in his veterinary bill.

Table 6

Costs and benefits of a 100 cow herd using a computerised dairy recording system

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Benefits						
profit	-1,500	2,500	5,500	5,500	5,500	17,500
Costs						
fees	700	700	700	700	700	3,500
vet bill	280	280	280	280	280	1,400
gross costs	980	980	980	980	980	980
Gross benefits minus gross costs	-2,480	1,520	4,520	4,520	4,520	1,260

Results	@ Discount rates :	5%	8%	10%	12%
	Net Present Value	10181.48	8993.95	8291.38	7652.01
	Benefit Cost Ratio	3.4	3.3	3.23	3.17

These calculations show that, for this set of assumptions, the benefits of the scheme substantially outweigh the costs at all discount rates. Further benefits that might be realised (either by starting from a worse position or by better usage of the management data generated by the system) would further increase the benefit cost ratio.

Veterinary Practice point of view

The benefits and costs to a veterinary practice installing a computerised dairy information system depend on three main factors:

a) the number of herds that can be joined at what rate;
b) the type of reporting in demand (interval) and hence the fees charged for the service;
c) the amount of extra consulting work generated on farms;
d) the level of variable costs incurred.

For the purpose of this example, the following assumptions are made:

a) the number of 100 cow herds on the system at the end of 1, 2 and 3 years are respectively 10, 20 and 30 (average for those years of 5, 15 and 25 herds);
b) weekly reporting is in demand at a fee level of £7.00 per cow per year;
c) vet work on farms is increased by 20%;
d) variable costs are high, at £5.00 per cow per year (table 5).

In addition, it is assumed that the financing of the project is by means of a bank loan for £8,000 which is paid back in five annual instalments of £2,000 (amortised at 8%), and the fixed costs are as laid out in table 5.

The benefit cost analysis is set out in table 7.

Table 7

Costs and Benefits of Installing a Computerised Dairy Recording System in a Veterinary Practice

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
cows on system	500	1,500	2,500	3,000	3,000	
benefits						
receipt of loan	8,000					8,000
fees	3,500	10,500	17,500	21,000	21,000	73,500
work	1,400	4,200	7,000	8,400	8,400	29,400
gross benefits	12,900	14,700	24,500	29,400	29,400	110,900
costs						
fixed	9,628	3,378	3,378	3,378	3,378	23,140
variable	2,500	7,500	12,500	15,000	15,000	52,500
gross costs	12,128	10,878	15,878	18,378	18,378	75,640
gross benefits minus gross costs	772	3,822	8,622	11,022	11,022	35,260

Results	@ Discount rates :	5%	8%	10%	12%
	Net Present Value	29353.76	26438.87	24710.20	23131.99
	Benefit Cost Ratio	1.45	1.45	1.44	1.44

The results show that the discounted benefits exceed the discounted costs at all discounting levels, indicating that the project is viable.

DISCUSSION

The results of the benefit cost analyses, although hypothetical, do indicate that substantial benefits can accrue, both to the farmer and to the veterinarians, as a result of the adoption of a microcomputerised dairy information system. This is in spite of the severity of the assumptions used in the analyses. It is important to appreciate, however, that such a system only provides information. Its success, therefore, depends on the ability and willingness of all the individuals concerned, from the herdsman to the vet, to take advantage of the opportunities offered by the system.

The successful practice of preventive medicine depends largely on the quantity and quality of information available. The individual who has control over the generation and, as importantly, the processing and analysis of that information, is the one most likely to be in a position to offer the best advice irrespective of his professional qualification. Logically this individual should be the veterinarian. It is up to the profession, however, to equip itself with the skills necessary to take full advantage of the opportunities offered by modern information technology.

REFERENCES

Bailie, J.H. (1980) Computer simularion of some economic and management aspects of oestrus control in beef and dairy cattle. Ph.D. Thesis, University of Reading.

Collick, D.W. (1982) The use of computer based dairy information systems in practice to improve herd productivity. Proceedings of the XIIth World Congress on Diseases of Cattle, September 1982, World Association for Buiatrics. p613-617.

Drew, S.B. (1982) Husbandry and financial aspects of the use of the progesterone releasing intravaginal device (PRID) in the management of dairy cows. Ph.D. Thesis, University of Reading.

Eddy, R.G. (1981) The application and some economic implications of a fertility control programme in large dairy herds. Thesis for F.R.C.V.S. November 1981.

Esslemont, R.J. (1982) Economic aspects related to cattle infertility and the postpartum interval. In: Current topics in veterinary medicine and animal science Vol. 20, H. Karg and E. Schallenberger (eds), Martinus Nijhof, The Hague. p442-458.

Esslemont, R.J. (1983) The economics of poor husbandry - the costs and benefits of fertility management. Proceedings of the Society for Veterinary Epidemiology and Preventive Medicine, Southampton, April 1983. p164-168.

Esslemont, R.J. and Ellis P.R. (1975) The Melbread dairy herd health recording scheme. University of Reading, Department of Agriculture and Horticulture. Study No.21.

James, A.D. and Esslemont R.J. (1978) The economics of calving intervals. J.Brit.Soc.An.Prod.

Stephens A.J., Esslemont R.J. and Ellis P.R. (1980) DAISY A dairy herd information system for small computers. In: Evaluation of Benefit-Costs of Animal Health Care Symposium at Michigan State University.

AN APPROACH TO THE MEASUREMENT OF THE COSTS AND BENEFITS OF POULTRY MEAT INSPECTION

A.P. POWER AND K.S. WARWICK*

The Poultry Meat (Hygiene) Regulations 1976 lay down the conditions which must be met in relation to poultry meat sold or prepared for sale for human consumption in England and Wales. The Regulations implement the provisions of EC Directive 71/118 (as amended) on health problems affecting trade in fresh poultry meat. Their purpose is to provide a public assurance that poultry meat is wholesome and that it is processed hygienically. In particular, the Regulations provide for the licensing of slaughterhouses and lay down requirements as to slaughter and evisceration procedures, ante- and post-mortem inspection and hygiene and control of operations. Local authorities are responsible for enforcing the Regulations and are entitled to make charges to cover the cost of running the licensing and inspection system. Similar provisions apply in Scotland and Northern Ireland.

The Regulations came fully into force in England and Wales on 15 August 1979. Inspection is carried out by trained local authority poultry meat inspectors (PMIs) under the supervision of an officially-designated veterinary surgeon (OVS). Now that the new system has been in operation for almost 5 years, an attempt can be made to make a preliminary assessment of its costs and benefits. This paper describes one possible approach to such an assessment.

BENEFITS AND COSTS OF THE INSPECTION SYSTEM

The most obvious benefit arising from a rigorous inspection system is the reduction in the number of diseased or unwholesome carcases reaching the consumer. The two most serious zoonoses known to be associated with poultry meat are salmonellosis and ornithosis but there is a wide range of other conditions which can render the carcase partially or wholly unfit for human consumption such as air sacculitis, salpyngitis, septicaemia and staphylococcal infections. Many of these conditions are not necessarily harmful to human health but affected poultry can show signs of discoloration, swelling or pus formation and hence may appear unwholesome or even repugnant to the consumer.

It is important to note that many of these conditions would not be obvious on casual inspection. Detection often requires knowledge of flock history, effective ante-mortem inspection and full inspection of carcase and viscera by a trained and supervised inspectorate. It is therefore likely that the more

---

*This paper was written when the authors were Senior Economic Adviser and Senior Economic Assistant respectively, with the Ministry of Agriculture, Fisheries and Food. Mr Warwick is now with the Foreign and Commonwealth Office. The authors thank Mr R. Malhi for programming assistance.

thorough inspection arrangements in force since 1979 will have resulted in fewer unwholesome poultry carcases reaching the dinner table than was the case under the old system.

On the cost side, the main element is of course the charge made by local authorities to recoup the cost of issuing licences, granting exemptions and carrying out inspection under the Regulations, including all their overhead expenses and related recruitment and training costs.

Another cost is imposed by the higher rejection rates under the more rigorous inspection system which results in a reduced supply of poultry to the market. Some of the birds held off the market may be completely inedible, but others may be partly edible though unwholesome and a proportion may be perfectly satisfactory. Some of the meat from partly edible birds may be salvaged as poultry cuts but the net effect will still be to reduce the total supply of poultry meat to the market. Another way of looking at the effect is that the higher rejection rates are assumed to add to processors' costs over and above the charges they have to pay for the direct cost of the inspection service.

The overall cost-benefit balance and the net impact on consumers and producers cannot be determined a priori. On the one hand, inspection imposes costs on producers but, on the other hand, consumers should be prepared to pay higher prices because of the higher average quality of poultry reaching the market and a reduction in the risk of getting an unsatisfactory carcase (an additional effect if consumers are risk averse, as is usually supposed). Prices are higher for producers but so are their costs; prices are higher for consumers but on average they are expected to be more satisfied with what they buy. The advantage of the simple model to be developed in this paper is that it allows these offsetting factors to be evaluated.

A SIMPLE SUPPLY-DEMAND MODEL

In order to quantify the measurable costs and benefits attributable to the inspection system and assess their relative importance, a simple supply-demand model will be constructed and used to measure the impact on producers and consumers. The measure of the gains and losses used is the change in consumer surplus and producer surplus. The concept of consumer surplus is best explained as follows. If consumers purchase commodity X at a price of £1 per unit they must all have been willing to pay at least £1 and some may have been prepared to pay more. Clearly then the total amount that consumers would have been willing to pay will be greater than or equal to the amount actually paid. The difference is termed consumer surplus. Similarly for producer surplus - no producer will regularly supply goods to the market unless the price obtained is at least equal to his marginal costs. Some will have marginal costs well below the ruling price but none will be able to sustain marginal costs above that price. The aggregate gap between revenue and total variable costs is producer surplus.

The two concepts are illustrated in the following figure:-

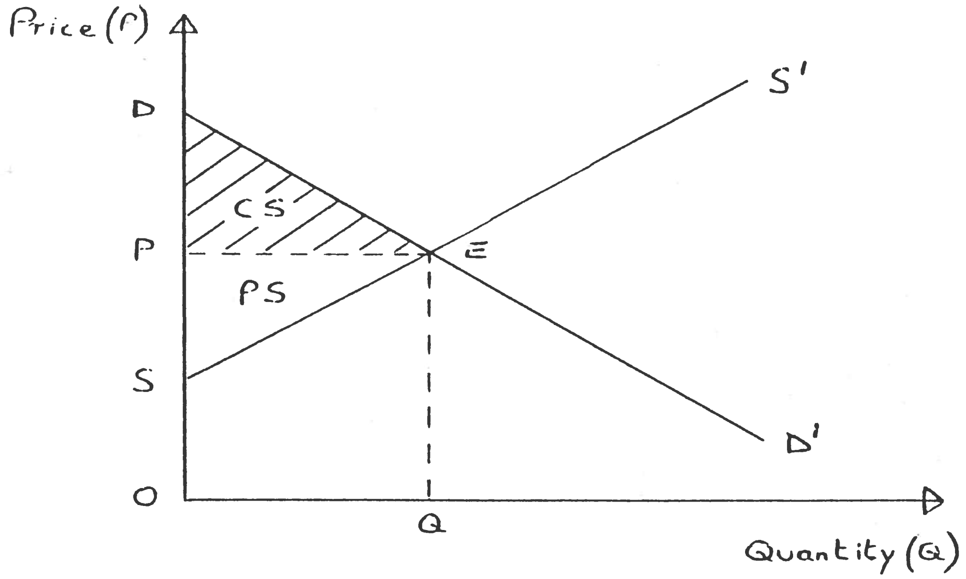


Fig. 1 Consumer and producer surplus

At the equilibrium price P and quantity Q, consumer surplus (CS) is the difference between consumers' total willingness to pay (represented by the area under the demand curve DEQO) and what they actually pay (PEQO), i.e. the shaded area DEP. Producer surplus (PS) is the difference between producers' revenue (PEQO) and their costs (represented by the area under the supply curve OSEQ, i.e. PES. What matters is not so much the absolute magnitude of these measures but how much they change when supply and demand curves shift.

The assessment involves comparing consumer and producer surplus in two equilibrium positions - one with the inspection system and the other without it. In Fig.2 subscripts are used to distinguish between the two positions - e.g. P_o represents equilibrium price under an inspection system and P_1 represents equilibrium price in the absence of an official system.

The diagram illustrates the main effects of the inspection system. First of all, charges levied by local authorities raise suppliers' marginal costs by an amount a' per unit, shifting the supply curve upwards from $S_1 S_1'$ to $S_c S'$. In addition, the higher rejection rates under an official inspection system mean that, at any given price, supply is greater without inspection than with it, by an amount b%. Finally, the demand curves differ because consumers' valuation or willingness to pay is less in the absence of an inspection system, by c%. The effect of an inspection system is therefore to shift the supply curve upward and inward and the demand curve upward. The resulting with-inspection equilibrium E_o is at a higher price (P_o) but the effect on the quantity supplied is ambiguous. The effect on producer and consumer surplus is also ambiguous but it can be shown that inspection brings net benefits if the shaded area between the demand curves exceeds the shaded area between the supply curves. Exact expressions can easily be derived algebraically for the case where supply and demand schedules are simple linear functions (as in Fig.2). An alternative specification of the supply and demand curves is considered, and its implications discussed, in a later section.

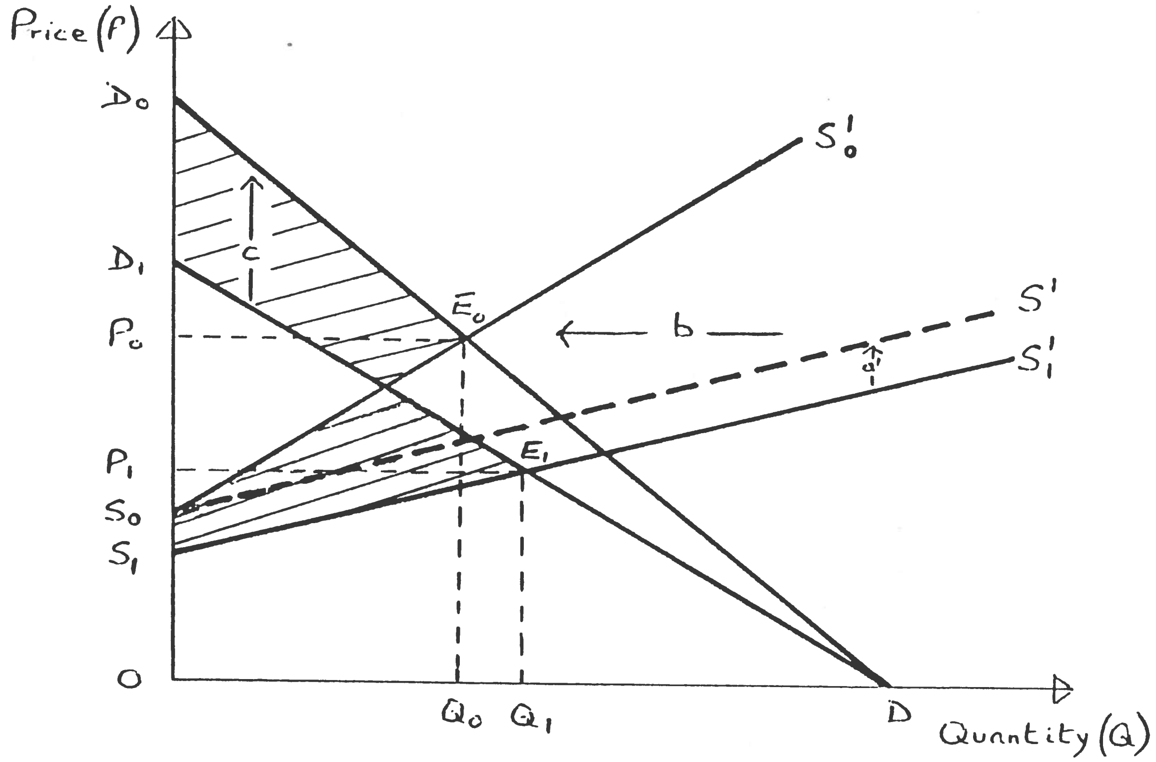


Fig. 2 Comparison of supply and demand with and without inspection

CHOOSING PARAMETER VALUES

The size of the changes in consumer and producer surplus depend on several parameters - inspection costs (a'), the effect on throughput (b), the demand shift (c), the price and quantity (P_o and Q_o) with inspection and the slopes of the supply and demand curves (k and -m). The values assumed for all these parameters (with the exception of c), the range of values chosen for sensitivity analysis and some explanatory comments are given in Table 1a.

The demand shift parameter c requires fuller discussion. The measure required is one of how much less consumers would be willing to pay for poultry in the absence of inspection because of the lower average quality and higher risk of obtaining a substandard carcase. The purchase of poultry can be thought of as involving an element of a gamble. If the gamble pays off, the consumer will have a perfectly satisfactory bird; but if not, the consumer will find, on carving the bird, that it is partly or wholly inedible. How much the consumer is prepared to pay for the bird will depend on the same sort of considerations relevant to the purchase of a lottery ticket, namely the odds, the prizes and the purchaser's degree of dislike of risk. The odds - the probability (call it π) of the bird turning out to be substandard - will depend on the thoroughness of inspection. The 'prize' in most cases will be a healthy carcase but in some it will be an unwholesome bird. Assume that the unwholesome bird is worth only a fraction $(1 - \delta)$ of the value of the healthy carcase. With the addition of a technical parameter for dislike of risk, known as the Arrow-Pratt measure of relative risk aversion (denoted by R), the demand shift parameter c can be estimated. Values of π, δ and R are shown in Table 1b, together with ranges for sensitivity analysis and some explanatory comments.

Table 1a. Parameter values

Parameter	Symbol	Central value	Range for sensitivity analysis	Standard deviation for Monte Carlo analysis	Comments
Inspection cost (p/lb)	a'	0.2	0.1 - 0.3	0.05	Based on estimates derived from experience with charges for inspection to date.
Difference in throughput (%)	b	0.8	0.6 - 1.0	0.2	Some evidence of rejection rates of about 2% limits the scope for throughput to be very much higher in the absence of inspection.
Price (p/lb)	P_o	45	-	-	Wholesale price of $3\frac{1}{2}$lb broilers.
Quantity (000 tonnes)	Q_o	780	-	-	Normalised production figure from MAFF Annual Review of Agriculture, 1984.
Demand elasticity	ε^D_R	0.9	0.6 - 1.2	0.25	Absolute value based on MAFF's National Food Survey analysis. The slope of the demand curve (-m) is derived from: $m = \frac{1}{0.6 \times \varepsilon^D_R} \times \frac{P_o}{Q_o}$ where 0.6 is the ratio of wholesale to retail price.
Supply elasticity	η^s	1.25	1.0 - 1.5	0.25	Best available estimate. The slope of the supply curve (k) is derived from: $k = \frac{1}{\eta^s} \times \frac{P_o}{Q_o}$

Table 1b. Parameter values

Parameter	Symbol	Central value	Range for sensitivity analysis	Standard deviation for Monte Carlo analysis	Comments
Probability of obtaining sub-standard bird now	π_0	0.005	-	-	No information to go on here but incidence of substandard birds on the market is presumably very low.
Relation between π and b	γ	0.6	0.3 - 0.9	0.25	γ represents the proportion of the extra output which would be substandard if rejection rates were lower. The probability of obtaining a substandard bird in the absence of official inspection system is then calculated as: $\pi_1 = \pi_0 + \gamma^b$
Down-valuation	δ	0.5	0.25–0.75	0.2	This represents an average down-valuation across a whole range of conditions, from the only slightly imperfect to the totally inedible. In all cases, it is assumed $\delta_0 = \delta_1$.
Risk aversion	R	2.5	2 - 3	0.5	A value of 2 - 3 is commonly used in the literature and is known as the "Samuelson presumption".

RESULTS AND SENSITIVITY ANALYSIS

Having decided on an appropriate framework and chosen suitable values for the parameters, it is relatively straightforward to calculate the net benefit or cost of having a poultry meat inspection system. The results of the main analysis, utilising the central estimates of parameters (Tables 1a and 1b) are as follows:-

	£ million
Effect on consumer surplus	-0.99
Effect on producer surplus	+0.84
Total effect	-0.15

Thus, the inspection system brings net benefits to producers and imposes slightly higher net costs on consumers. The calculations underlying these results confirm that equilibrium price is higher under the inspection system but by only 0.4p per lb. Equilibrium production is marginally lower but only by 2000 tonnes. To put these changes in perspective, total UK poultry production is of the order of 780,000 tonnes, worth about £750m at wholesale prices. The costs and benefits of the inspection system are therefore seen to be very finely balanced, with small gains to producers at consumers' expense. However, as will be shown, this conclusion has to be modified slightly in the light of sensitivity tests.

The results of a first group of sensitivity tests are given in Table 2 where the effect of changes in the assumptions about individual parameters is examined. Some results are easily predicted - both producers and consumers gain more (or lose less) from the inspection system the lower are inspection costs, the higher is consumers' risk aversion and the greater is the extent to which diseased or unwholesome birds are down-valued. One result is somewhat surprising - the inspection system proves to be more favourable the greater the reduction in supply brought about by increased rejection rates. This arises because of the assumption that 60% of the output rejected would have been unsatisfactory to consumers and the perceived benefits to consumers outweigh any losses because of reduced supplies. With a proportion lower than 60%, less down-valuation of unfit birds or lower risk aversion, a different picture might emerge.

The impact of changing supply and demand elasticities is difficult to predict. From Table 2 it emerges that consumers lose less from the inspection system, and producers gain more, the more inelastic is demand and the more elastic is supply. However, there is evidence that the direction of effect of the supply elasticity on producer gains depends on the values taken for other parameters. In general this may be true of a number of parameters and serves as a warning that the cumulative effect of parameter variations may differ from the sum of the individual effects.

Further examination of Table 2 reveals that, overall, the results are reasonably robust with respect to changes in parameters relating to risk aversion, differences in throughput and in both elasticities (although there is some evidence that the consumer effect becomes very sensitive to the demand elasticity when it falls below 0.6). Parameters which markedly affect the results are the cost of inspection, the proportion of the reduction in throughput which is diseased or unwholesome and the extent of the down-valuation of birds known to be unfit. These three parameters should be the focus of further research to establish firmer estimates of their value.

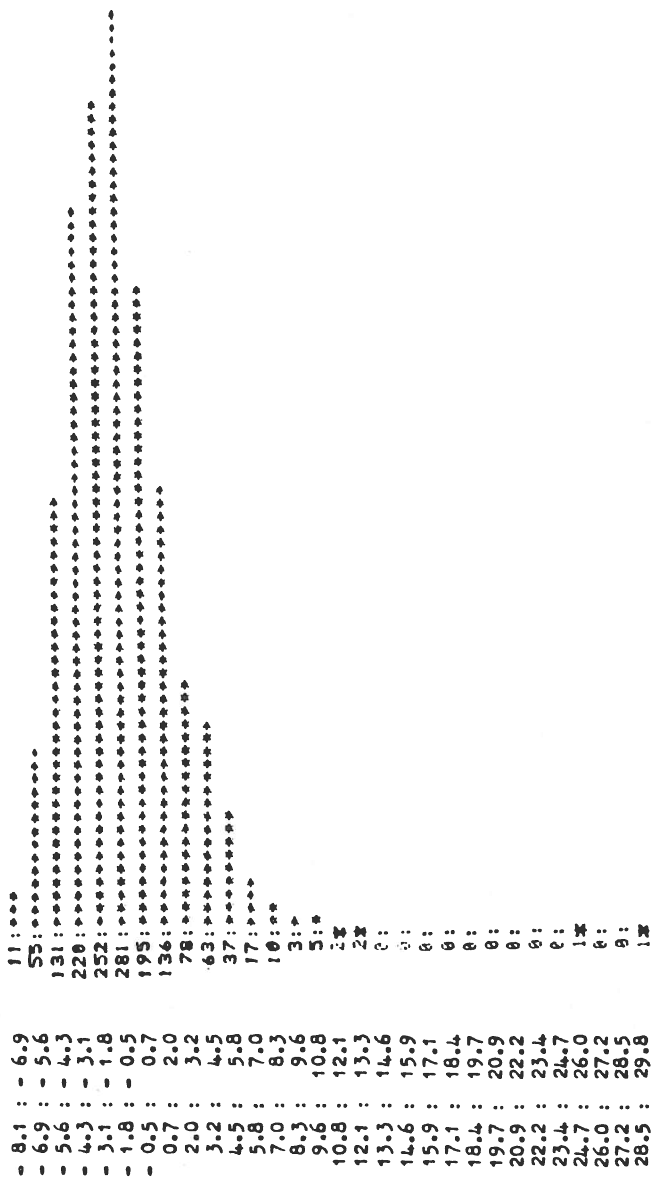
Table 2. Sensitivity of results to individual parameter values

		Value of inspection system (£m)		
		Consumer effect	Producer effect	Total effect
Central estimate		-0.99	+0.84	-0.15
Sensitivity to:				
Inspection costs	$a' = 0.1$p/lb	0.21	1.36	1.57
	$a' = 0.3$p/lb	-2.20	0.32	-1.88
Throughput effect	$b = 0.6\%$	-1.35	0.37	-0.97
	$b = 1.0\%$	-0.64	1.31	0.67
Demand elasticity	$\varepsilon_R^D = 0.6$	-0.03	1.26	1.23
	$\varepsilon_R^D = 1.2$	-1.34	0.50	-0.85
Supply elasticity	$\eta^s = 1.0$	-1.53	0.77	-0.76
	$\eta^s = 1.5$	-0.59	0.85	0.26
π-b relation	$\gamma = 0.3$	-3.42	0.39	-3.02
	$\gamma = 0.9$	1.42	1.29	2.70
Down-valuation	$\delta = 0.25$	-3.88	0.31	-3.57
	$\delta = 0.75$	2.77	1.53	4.30
Risk aversion	$R = 2$	-1.35	0.77	-0.58
	$R = 3$	-0.64	0.90	0.27

Table 2 also confirms how finely balanced are the results. It can be seen that uncertainty over any one parameter can mean the difference between a small net benefit and a small net cost for the inspection system. The range of outcome is of course much wider when more than one parameter assumption is allowed to vary. For example, combining the parameter values in Table 2 which gave the lowest estimates of the benefit of the inspection system gives a net cost of £6.73m of which consumer losses are £5.15m. Conversely, a combination of the 'best' parameter values gives a net benefit from inspection of £21.31m, of which consumer gains are £18.0m. This appears to suggest that the results of the main analysis may be biased. However, there are reasons why this may not be so. In the first place, 'worst-best' ranges derived in this way may not represent the true extremes of the possible range. It has already been noted that the direction of effect of changing one parameter may be reversed when the values of other parameters are also changed. Because of this inter-dependence it would be necessary to examine all possible combinations of parameters to find the true 'worst-best' range. A second reason is that no indication of the likelihood of the 'best' and the 'worst' outcome is given. Thus if the probability of large gains to consumers from inspection is very low, then the results of the main analysis may be reasonably unbiased.

Monte Carlo analysis

Given these difficulties with 'worst-best' ranges, an alternative approach to examining variations in several parameters is adopted. This is a technique known as Monte Carlo analysis. The technique depends on assigning a probability to each of the possible values of each of the parameters. Specifying a probability distribution for each parameter is in principle sufficient to determine a probability distribution for the estimated value of the inspection system, but in practice the latter distribution is too complex to be determined analytically. Instead, the Monte Carlo procedure derives the distribution by repeated experimentation: a value for each

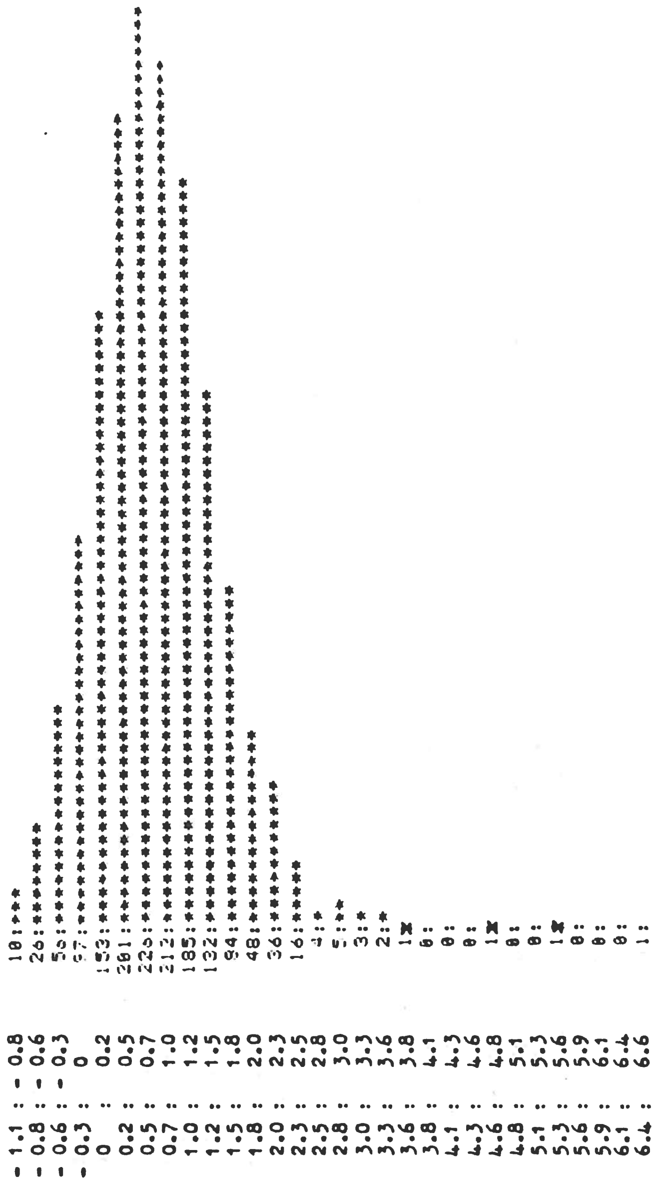


Mean	:	- 0.457
Standard Deviation	:	3.249
Maximum	:	29.761
Minimum	:	- 8.117

Fig. 3a Results of Monte Carlo analysis - consumer effect

parameter is drawn at random from its own specified distribution and the consumer and producer effects are computed; the whole procedure is then repeated many times over and all the results are plotted in a histogram. The main features of the distribution - mean, mode, standard deviation, skewness and any pecularities - are then indicated by the histogram rather than determined theoretically.

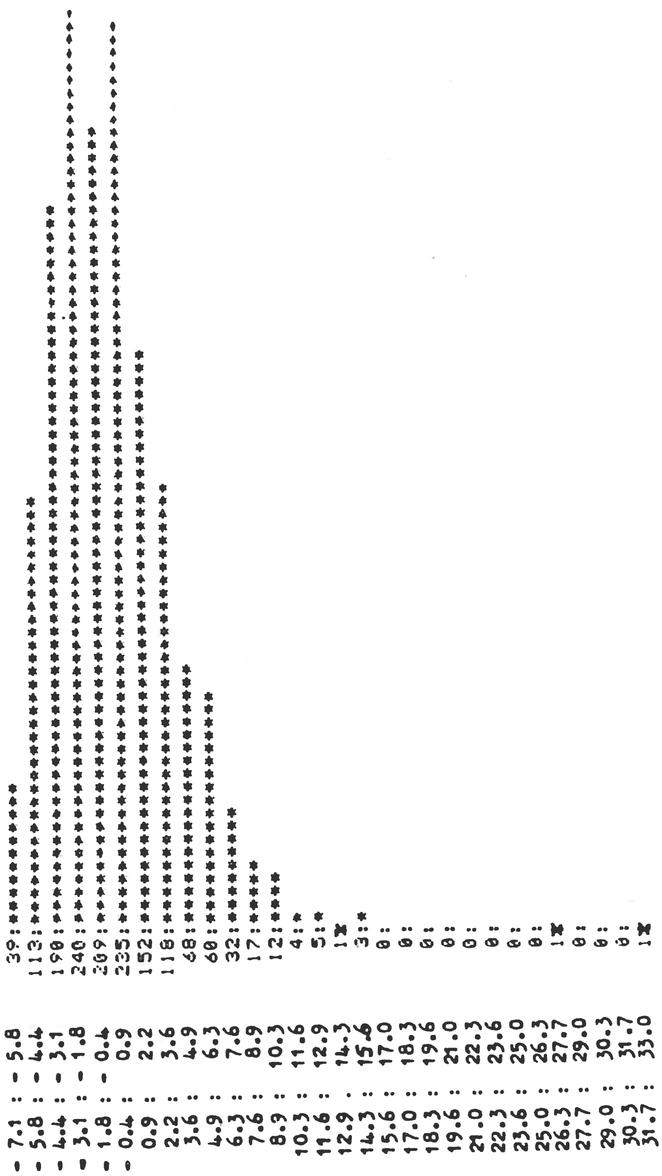
In order to implement this technique it was assumed that the values of the individual parameters are independently and normally distributed about the central values used in the main analysis, with standard deviations as listed in the fifth column of Table 1a and 1b. In practice, 1500 repetitions were found to be sufficient to give reasonably smooth and stable distributions both for individual parameters and for the end result.



Mean	:	0.880
Standard Deviation	:	0.732
Maximum	:	6.627
Minimum	:	- 1.064

Fig. 3b Results of Monte Carlo analysis - producer effect

Figures 3a, b and c show the results of the Monte Carlo exercise for the producer, consumer and total effects respectively. A number of interesting points emerge. First the mean result of the 1500 repetitions is a £0.46m consumer cost and a £0.88m producer benefit from the inspection system. Thus the consumer cost is found to be only marginally smaller than in the central analysis, suggesting that the latter is in fact only slightly biased and confirming the fine balance of costs and benefits. The distribution around the mean is fairly compact in the case of producer surplus but much less so for consumer surplus. The shape of the distribution is quite smooth in both cases but there is evidence of a long right hand tail to the distribution from the presence of positive outliers, particularly for the consumer effect. The presence of outliers was also noted in other Monte Carlo runs and they seem tó be associated with particularly low values for the demand elasticity.



Mean	:	0.422
Standard Deviation	:	3.375
Maximum	:	33.004
Minimum	:	- 7.120

Fig. 3c Results of Monte Carlo analysis - total effect

However, while they cannot be ignored, the occurrence of outliers is extremely rare and the great bulk of the out-turns fall within a relatively narrow range: 90% between -£0.3m and +£2.0m for producers and 90% between -£5.6m and +£4.5m for consumers.

Alternative form of the model

So far sensitivity analysis has been carried out involving individual parameters and combinations of parameters. Also of interest is the sensitivity of the results to the assumption that the supply and demand curves are simple linear functions. An alternative specification would be that they are log-linear in form. The difference between the two formulations is illustrated in Fig.4 below with linear supply and demand schedules shown as broken lines and the log-linear curves as solid lines.

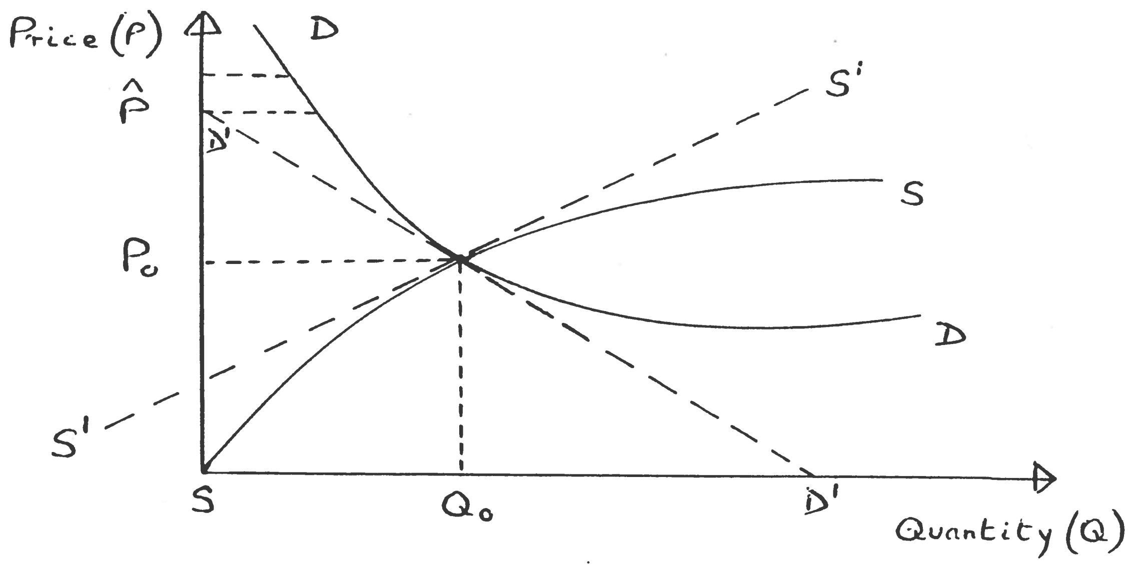


Fig. 4 Comparison of linear and log-linear demand and supply curves

The two approaches could give very different estimates of producer and consumer surplus. For producer surplus, the difference will not be great as long as the elasticity of supply is close to 1.0 (as is the case for poultry); this is because unit-elastic supply curves are all straight lines through the origin. However, the growing divergence between the two demand curves (DD and D'D') as they approach the vertical axis means that estimated consumer surplus will be much higher in the log-linear case. In fact, strictly, it is infinite since DD never reaches the axis. In order to arrive at any finite measure it is necessary to assume a price level above which demand could be expected to be zero and truncate the demand curve at that point. A possible price to choose is $\hat{P}$ at which the linear demand schedule meets the vertical axis. In that case, the value of the inspection system is put at £0.83m with consumers benefiting by £0.27m and producers by £0.56m. If a higher cut-off point is chosen, the estimate of consumer benefit becomes even larger. For example, if a maximum price of £10 per lb is assumed, then the consumer gain reaches £16.8m and the total benefit of inspection is put at £17.4m. Thus, while the log-linear version confirms that producers are net beneficiaries of the inspection system, it suggests that consumers may also benefit, perhaps substantially.

Which model is the more plausible? A reasonable supposition is that the demand curve bends upwards (like the log-linear curve) but then turns back towards the vertical axis (see Fig. 5). It is also likely that it reaches the vertical axis at a point higher than $\hat{P}$ (which represents a price of £1.28 per lb assuming a demand elasticity of 0.9).

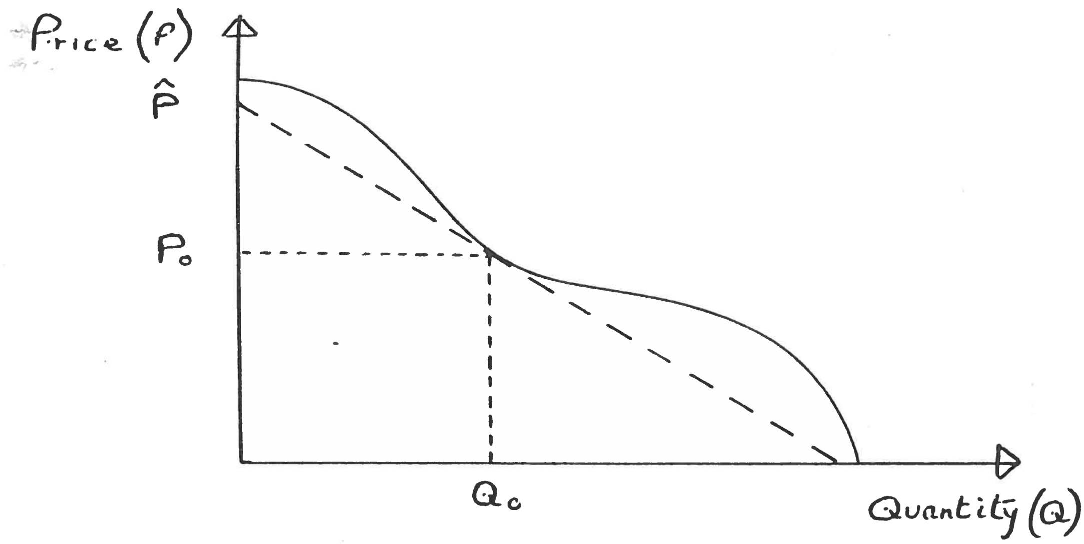


Fig. 5 A plausible demand curve

The true shape is probably closer to the log-linear curve with cut-off than to a straight line. If this is indeed the true shape, then the results of the simple linear model understate the value of inspection to consumers, but because of the difficulty of determining an appropriate cut-off point for the log-linear demand curve, it is difficult to be more precise.

SUMMARY AND CONCLUSION

In the preceding sections we have sought to show how simple economic concepts can be used to evaluate some of the costs and benefits of veterinary work, in this case the activities of OVSs and PMIs in implementing poultry meat inspection arrangements. A simple supply-demand model has been developed and the basic concepts of producer and consumer surplus introduced. A method has also been described for assessing the demand effect of the consumer protection element of current inspection arrangements. Results have been computed but the main emphasis has been on the importance of sensitivity analysis - both on individual parameters and on combinations of parameters by means of Monte Carlo techniques. A final sensitivity analysis looked at an alternative specification of the model and discussed how the results would differ.

The outcome of the main analysis, based on best available estimates of the relevant parameters, is that poultry meat inspection arrangements bring small net benefits to producers and slightly higher net costs to consumers. However, as sensitivity tests indicate, the results are finely balanced and Monte Carlo analysis shows that, under certain assumptions, consumers derive substantial benefits from the inspection system. Moreover, under the alternative and arguably more plausible specification of the model, the consumer effect is generally positive, often substantially so, although exact quantification is difficult. Finally, there may be other benefits of the inspection system which we have not attempted to quantify such as the feedback of information on flock health from the processor to the farmer.

Taking all these factors into account, it is more likely than not that the current system of poultry meat inspection does bring net benefits to both producers and consumers and hence to the economy as a whole.

THE FINANCIAL CONSEQUENCES OF AN OUTBREAK OF ABORTION IN A DAIRY HERD

D J BATES*, J D CORKISH** AND G DAVIES***

Although a major cause of bovine abortion, brucellosis, is being eradicated from British herds, outbreaks of abortion still occur sporadically. These may be due to Salmonella or mycotic abortion but more often the cause is unknown. Whatever the cause the herd owner has to decide whether to persist with the aborted cows or to sell them and buy replacements. He takes these decisions on financial grounds but there is no published work indicating the likely milk yield after an abortion or the financial consequences of the courses open to him.

This paper describes a method of calculating the financial loss from retaining aborted cows in the herd and then uses this method to calculate the loss in an actual abortion case. A method for calculating the loss when cows are replaced is also shown.

OPTION: KEEPING ABORTED COWS

The construction of a model for calculating the financial loss from the abortion.

It is assumed that:

a) cows calve in mid January with a calving intervals of 365 days.

b) The period in milk prior to abortion is 7-7$^1/2$ months i.e. the cow aborts in the second half of August after approximately 4$^1/2$ months gestation.

c) The cow subsequently holds to service about 8 weeks later - by the end of October and calves again about mid August i.e. 12 months after the abortion.

d) The yield potential per cow in a normal lactation is 5500 litres.

e) The Dairy cow performance (as predicted by the ADAS dairy herd forecast programme) is:

Calving date	Yield (Ltrs/cow)	Milk price (p/Ltr)	Concentrates (Kg/Ltr	Margin over Concentrates
January	5549	14.61	0.30	550
August	5576	15.03	0.37	520

*MAFF, Farm Management Service, Wolverhampton
**Veterinary Investigation Centre, Shrewsbury
***Epidemiology Unit, Central Veterinary Laboratory, Weybridge

f) After abortion the aborted cow milks on for a further 5 months i.e. to the end of January as follows:

Milk yield/cow/day

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Normal calving	15.5	12.5	10.2	8.0	6.6		
Aborted cow	15.5	12.1	13.0	10.4	8.3	7.9	7.5

g) The aborted cows produce 6 litres a day from grass in August and 4 litres in September. They produce 6 litres a day from silage from October to January.

The losses due to abortion consist of:

1. The loss of margin over concentrates (milk sales less the cost of concentrates - M.O.C.)
   This is calculated by averaging the monthly cumulative loss in MOC for a 12 months period commencing with the month of peak loss i.e. August of the second year (Table 1 and Fig.1).

2. The loss of the calf - calculated by proportioning the value of the calf (£70) according to the delay in calving as a result of the abortion (7 months).

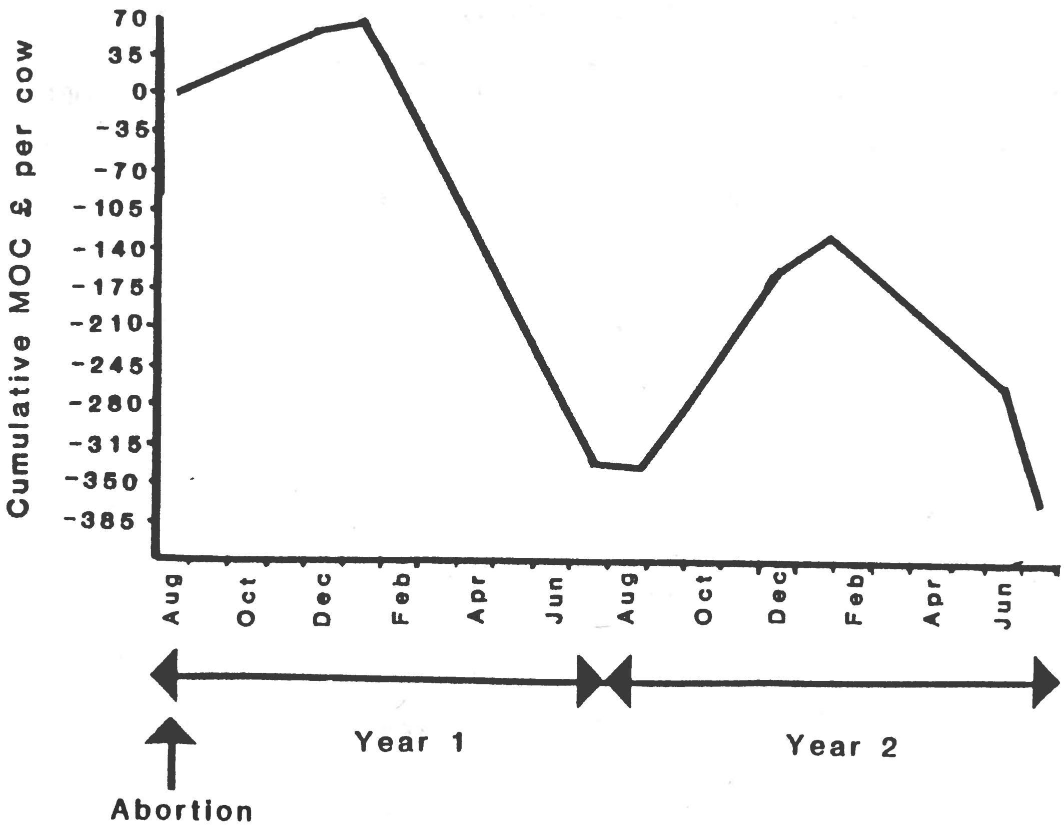


Fig.1 Cumulative loss of margin over concentrates (MOC) £ per cow

Table 1 Calculation of margin over concentrate (MOC) loss

	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July
Year 1												
MOC from Aborted Cow	42	41	40	33	33	32	0	0	0	0	0	0
MOC from Non Aborted Cow	43	34	29	15	0	30	64	68	56	83	72	56
Loss of MOC due to Abortion	-1	+7	+11	+18	+33	+2	-64	-68	-56	-83	-72	-56
Cumulative loss of MOC	-1	+6	+17	+35	+68	+70	+6	-62	-118	-201	-273	-329
Year 2												
MOC from Aborted Cow	38	85	72	58	50	51	40	39	32	39	16	0
MOC from Non Aborted Cow	43	34	29	15	0	30	64	68	56	83	72	56
Loss of MOC due to Abortion	-5	+51	+43	+43	+50	+21	-24	-29	-24	-44	-56	-56
Cumulative loss of MOC	-334	-283	-240	-197	-147	-126	-150	-179	-203	-247	-303	-359

Monthly cumulative MOC losses August to July of 2nd Year

August	334
September	283
October	240
November	197
December	147
January	126
February	150
March	179
April	203
May	247
June	303
July	359
	2768

Average monthly loss of MOC = £231/cow

3. Extra veterinary and A I charges.

4. Interest charges on the increase in bank overdraft due to the abortion loss. These are calculated from the difference in monthly cash flow where there is:

   a) no abortion and (b) abortion (Table 2)

The four elements of the losses are summed up as follows:

	£/cow
MOC - average monthly cumulative loss	231
Calf - loss of value $\frac{7}{12}$ x £70	41
Veterinary and AI charges	35
Total Loss	307
Bank interest charges at 13% in 2nd year	44*

*The interest charge per cow will be a continuing annual loss.

A CASE STUDY IN THE LOSS DUE TO ABORTION

i A Shropshire Fresian herd experienced an abortion storm in the period August 1982 to October 1982. The herd comprised 172 milking cows and heifers, and the cows were fed a complete diet during the winter period.

ii The number of abortions and the lactation ages of the cows involved were as follows:

Lactation	No. aborting	% of abortions
1	6	27
2	5	23
3	5	23
4	1	5
5	1	5
6	2	9
7	2	9
	22	

iii Four cows were culled after abortion (three in November and one in September). Three had foot problems and one was a low yielder.

iv Average time in milk prior to abortion (22 cows) - 7$^1/_2$ months
" " in calf " " " " " - 5$^1/_2$ months
" period aborting cows (22) continued in milk - 4$^1/_2$ months

Table 2 Cash flow projection - to show the effect of abortion on bank balance

YEAR 1	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	TOTAL
Cash flow with Abortion													
MOC - cows milking on after Abortion	42	41	40	33	33	32	0	0	0	0	0	0	221
Less Vet & AI	20	15											35
SURPLUS A	22	26	40	33	33	32	0	0	0	0	0	0	186
Cash flow without Abortion													
MOC	43	34	29	15	0	30	64	68	56	83	72	56	550
Calf						70							70
SURPLUS B	43	34	29	15	0	100	64	68	56	83	72	56	620
SURPLUS/DEFICIT due to Abortion (before Interest) A-B	-21	-8	+11	+18	+33	-68	-64	-68	-56	-83	-72	-56	-434
Interest @ 13% [a]	0	-0.23	-0.32	-0.20	-0.01	+0.35	-0.38	-1.08	-1.83	-2.46	-3.38	-4.20	-13.74
SURPLUS/DEFICIT after Interest	-21	-8.23	+10.68	+17.80	+32.99	-67.65	-64.38	-69.08	-57.83	-85.46	-75.38	-60.20	-447.74
Cumulative Bank balance	-21	-29.23	-18.55	- 0.75	+32.24	-35.41	-99.79	-168.87	-226.70	-312.16	-387.54	-447.74	

[a] Charged on balance at beginning of month

Balance @ 1st August = Nil

Table 2 cont'd

YEAR 2	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	TOTAL
Cash flow with Abortion MOC - from dalayed calvings	38	85	72	58	50	51	40	39	32	39	16	0	520
Calf	70												70
SURPLUS A	108	85	72	58	50	51	40	39	32	39	16	0	590
Cash flow without Abortion MOC	43	34	29	15	0	30	64	68	56	83	72	56	550
Calf						70							70
SURPLUS B	43	34	29	15	0	100	64	68	56	83	72	56	620
SURPLUS/DEFICIT Due to Abortion (before Interest) A-B	+65	+51	+ 43	+ 43	+ 50	- 49	- 24	- 29	- 24	- 44	- 56	- 56	- 30
Interest @ 13%	-4.85	-4.19	-3.69	-3.27	-2.84	-2.32	-2.88	-3.17	-3.52	-3.82	-4.34	-4.99	-43.88
SURPLUS/DEFICIT after Interest	+60.15	+46.81	+39.31	+39.73	+ 47.16	-51.32	- 26.88	- 32.17	- 27.52	- 47.82	-60.34	-60.99	-73.88
Cumulative bank balance	-387.59	-340.78	-301.47	-261.74	-214.58	-265.90	-292.78	-324.95	-352.47	-400.29	-460.63	-521.62	

Bank balance @ 1st August = £447.74

v Average lactation length of aborted cows (22) - 12 months
(Range 9 months 21 days to 15 months 2 days)
Average time from abortion to second calving - 11 months

vi Average yield - 6400 litres per cow
Average concentrate feed rate - 0.3 Kg per litre

<u>Calculation of financial loss (18 cows remaining in herd)</u>

	£/cow
MOC Average Monthly loss*	282
Calf - loss of value $\frac{7}{12}$ x £90	53
Veterinary and AI charges	36m
Total loss	371

Bank interests charges @ 13% in second year £54
*Calculated as the difference between the MOC for the 18 cows aborting and the remainder of the herd.

OPTION: REPLACING ABORTED COWS

The assumptions for this instance were:

1. Aborted cows milked on until the end of December i.e. the end of the month prior to the original calving date.

2. Cows bought in to calve at the original calving date (January) so as to maintain the calving pattern.

3. The purchased cows had already calved and had a yield potential similar to the cows sold.

4. The levels of dairy cows performance (yield, feed, MOC and milking on rate) were as in the previous calculations for keeping aborted cows.

5. Interest charges calculated using the same methods as for keeping aborted cows.

Calculation of financial loss:

		£/cow
Purchase Price	650	
Loss of calf sale	70	
Extra veterinary costs	15	
		735
Less		
Sale of cull cow	400	
Gain in MOC from aborted cow milking on	68	
		468
Total Loss		267

Bank interest charges at 13% in second year - 39

DISCUSSION

There are several methods by which the financial loss resulting from retaining aborted cows in the dairy herd can be calculated. This paper discusses one method and other methods will show a higher or lower financial loss. The assumptions used in the described method are estimates based on the data from a few case studies and the limited information available from published literature.

Whilst there may be no "best" method the general opinion is that the method used here is an acceptable compromise and gives a reasonable guide to the expected loss from abortion.

The loss due to abortion will vary depending on individual farm circumstances and when calculating the loss or deciding whether or not to keep or replace the aborted cows the following are the main factors to consider when making your assessment:-

<u>Keep Aborted Cows</u>

a) Milk produced after abortion:-
   Yield/day
   Rate of decline
   Length of milking on period
b) Level of feed to aborted cows
c) Cost of health/fertility complictions
d) Cost of calf lossess
e) Milk yield in next lactation
f) Effect on herd calving pattern

<u>Replace Aborted Cows</u>

a) Milk produced after abortion
b) Level of feed to aborted cows
c) Cost of health complications
d) Value of lost calf sales or can cows be bought in-calf?
e) Milk yield of purchased cow
f) How soon to buy replacement effect on calving pattern

g) Time taken to get back in calf
h) Level of herd performance - MOC

g) Cost of the purchase cow
h) Value of the cull cow
i) Cows or Heifers bought - Heifers have a lower yield but will last longer in the herd.

Keep or Replace Aborted Cows

The loss calculation from selling the aborted cow is £40 lower than from keeping it (£267) as against £307). Thus one might draw the conclusion that aborted cows should always be sold. This will not necessarily be the case; every case should be considered on its merits taking account of all the points referred to above which will vary from farm to farm. The £40 per cow advantage is not great when one considers the variation in cow purchase price, value of cull cows and the yield potential of the purchased cow.

A point to bear in mind is that there is time to make up ones mind - you have time to see how well the cow is milking on and if there appears to be any difficulty in getting her back in calf before deciding whether or not to replace her. Broadly speaking if the cow milks on well and is easily got back in calf then, unless the purchase price of cows is low relative to cull cow price, the cow is more likely to be kept and vica versa.

To produce a more accurate calculation of average loss then further information is required especially in relation to:-

a) The average time in milk at which abortion occurs.
b) The average time in calf at which abortion occurs.
c) Are a) and b) related?
d) The milk production after abortion which depends on the rate of decline and length of milking on period.
e) Time taken to get back in calf.

MODELLING

AN INTRODUCTION TO TECHNIQUES OF VETERINARY MODELLING

M.V. THRUSFIELD* AND G. GETTINBY**

Modelling dates back to the nineteenth century. Descriptive medical statistics, begun in Britain by John Graunt who published 'Bills of Mortality' in the seventeenth century, was developed over the next 200 years. Morbidity and mortality data were available for diseases such as smallpox by the middle of the nineteenth century. Mathematical models were proposed by medical statisticians to explain the observed mortality rates (Greenwood, 1943). The course of the 1866 British rinderpest epidemic was predicted by one of these early investigators, William Farr (quoted by Brownlee, 1915), using a simple epidemic model.

The early models, which founded general theory, described natural epidemics of human infectious diseases. Only within the last 20 years has significant attention been paid to the modelling of animal diseases. In addition to modelling natural epidemics, the effects of prophylactic and therapeutic techniques, such as vaccination and administration of anthelmintics, have been included in these mathematical representations. The effects of economic constraints and implications have, of necessity, been incorporated in the more recent formulations.

Density and prevalence models

Veterinary modelling has been directed towards infectious diseases, though non-infectious ones can also be modelled. Infectious agents can be classified into two groups according to their generation dynamics : microparasites and macroparasites. The microparasites multiply when they are inside the host, increasing the level of parasitism. They include viruses, bacteria, protozoa, chlamydiae and rickettsiae. Although macroparasites may reproduce within or on the host as part of their life-cycle, the level of parasitism is not usually increased. These include helminths and arthropods.

The two different dynamic patterns lend themselves to two different types of modelling. Density models consider the absolute number of infectious agents in each host and are commonly used in macroparasitic infections, where numbers of infectious agents can be estimated either in the host or in the environment. Enumeration of absolute numbers of microparasites is impracticable, because of their rapid rate of replication, and so these cannot be readily modelled using density techniques. These are frequently studied using prevalence models which consider the presence or absence of infection in various host cohorts, for example young and mature, immune and susceptible. The density model is potentially the more refined of the two techniques because it attempts to enumerate the number of infectious agents with which a host is challenged.

*Department of Animal Health, Royal (Dick) School of Veterinary Studies, University of Edinburgh.

**Department of Mathematics, University of Strathclyde, Glasgow.

Density and prevalence models can be produced by three approaches. This paper is a scholium of these approaches, with examples.

MODELS USING DIFFERENTIAL CALCULUS

These models generally involve establishing equations in terms of the rate of change of either the number of parasites or the number of hosts, or subsets of these populations, with respect to time.

Exponential decay paradigm: One of the earliest and simplest examples of such models is that of exponential decay.

The instantaneous rate at which susceptibles in a population become infectives, denoted by dx/dt (where dx is the change in the population in the small time interval dt), is assumed to be directly proportional to x (the number of susceptibles in the population)

$$\frac{dx}{dt} = -\alpha x.$$

In the model, α is a positive number that remains constant and is known as a parameter. If an input condition is known, such as the number of susceptibles in the population at time 0, then solving the equation leads to

$$x_t = Ne^{-\alpha t}$$

where x_t and N are the numbers of susceptibles in the population at times t and 0 respectively and e is the universal exponential constant: 2.718. If x_t is plotted for different values of t a curve is obtained showing x_t decreasing rapidly for small values of t and thereafter more slowly.

The early models of simple epidemics assumed that no infectives were removed from the population during the course of the epidemic. This assumption was incorporated into one of the first models - the Reed-Frost model - which, though only described in full relatively recently (Frost, 1976), formed the basis of many early models. Although this assumption may sometimes be valid in human epidemics, it is frequently untrue of animal epidemics - infectives are often removed by culling. Recently, attempts have been made to model animal epidemics with regard to this difference (Takizawa et al, 1977).

The earlier models also assumed that a group was of a given size with homogeneous mixing and that a susceptible individual was infectious as soon as it was infected: that the infection had no incubation or latent period. Most infectious diseases have latent periods and, in many situations, mixing is rarely homogeneous and individuals may become immune. Models have been produced which take account of these factors. Additionally, only a few diseases such as rabies and foot-and-mouth disease are sometimes characterised by interepidemic periods when no cases of disease occur. Most diseases are endemic to a varying degree, and it is possible to have recurrent epidemics, requiring different models.

Sheep vaccination paradigm: The following example demonstrates how immunity could be included in the simple exponential decay model. Suppose a flock of sheep is constantly under challenge from an infectious agent, infection with which usually causes death. The rate at which animals die is once again assumed to be in direct proportion to the number of animals that are under challenge and that are susceptible to infection. If a certain proportion of the animals shows symptoms and can be treated with a vaccine which provides temporary immunity then these animals will not die. Once the protection of the vaccine ceases these immune animals become susceptible once more and risk mortality. The system is illustrated by the two compartments shown in Fig. 1.

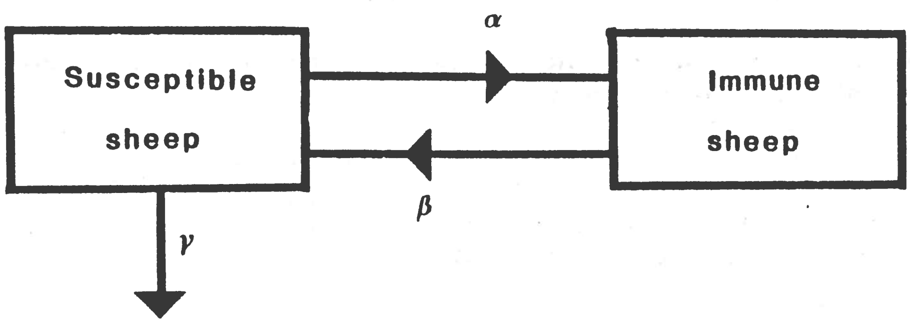


Fig. 1 Compartmental representation of a sheep vaccination model.

The left-hand compartment represents the susceptibles under challenge. Animals in this compartment may either die at rate γ or be identified for vaccine treatment and so become transferred at rate α to the right-hand compartment which represents the immune animals. When immunity ceases these animals return to the susceptible group at rate β. The model consists of two equations, one for the rate of change of susceptible animals, dx/dt, and one for the rate of change of immune animals, dy/dt:

$$\frac{dx}{dt} = - \alpha x - \gamma x + \beta y$$

and

$$\frac{dy}{dt} = \alpha x - \beta y.$$

Losses from the susceptible group due to mortality and vaccination are in proportion to the number in the group and are the terms $-\alpha x$ and $-\gamma x$ on the right-hand side of the equation for dx/dt. Animals returning to the susceptible group, however, lose immunity in proportion to the number in the immune group. This movement into the susceptible group is denoted by $+\beta y$. Similarly, the rate of change of animals in the immune group is the nett result of the gain αx and loss $-\beta y$. Standard methods of solution enable expressions for x and y to be obtained in terms of t:

$$x = \frac{N}{(a-b)} \{(\beta-b)e^{-bt} - (\beta-a)e^{-at}\},$$

and

$$y = \frac{N\alpha}{(a-b)} \{e^{-bt} - e^{-at}\},$$

where

$$a = \tfrac{1}{2}[(\alpha+\beta+\gamma) + \{(\alpha+\beta+\gamma)^2 - 4\gamma\beta\}^{\frac{1}{2}}],$$

$$b = \tfrac{1}{2}[(\alpha+\beta+\gamma) - \{(\alpha+\beta+\gamma)^2 - 4\gamma\beta\}^{\frac{1}{2}}]$$

and N is the size of the flock at time 0. Figure 2 shows the trends in the numbers of susceptible and immune animals. These are only *general* trends; the *exact* trend will depend on the values assigned to the parameters α,β and γ. It can be seen that the numbers in the susceptible group decrease rapidly

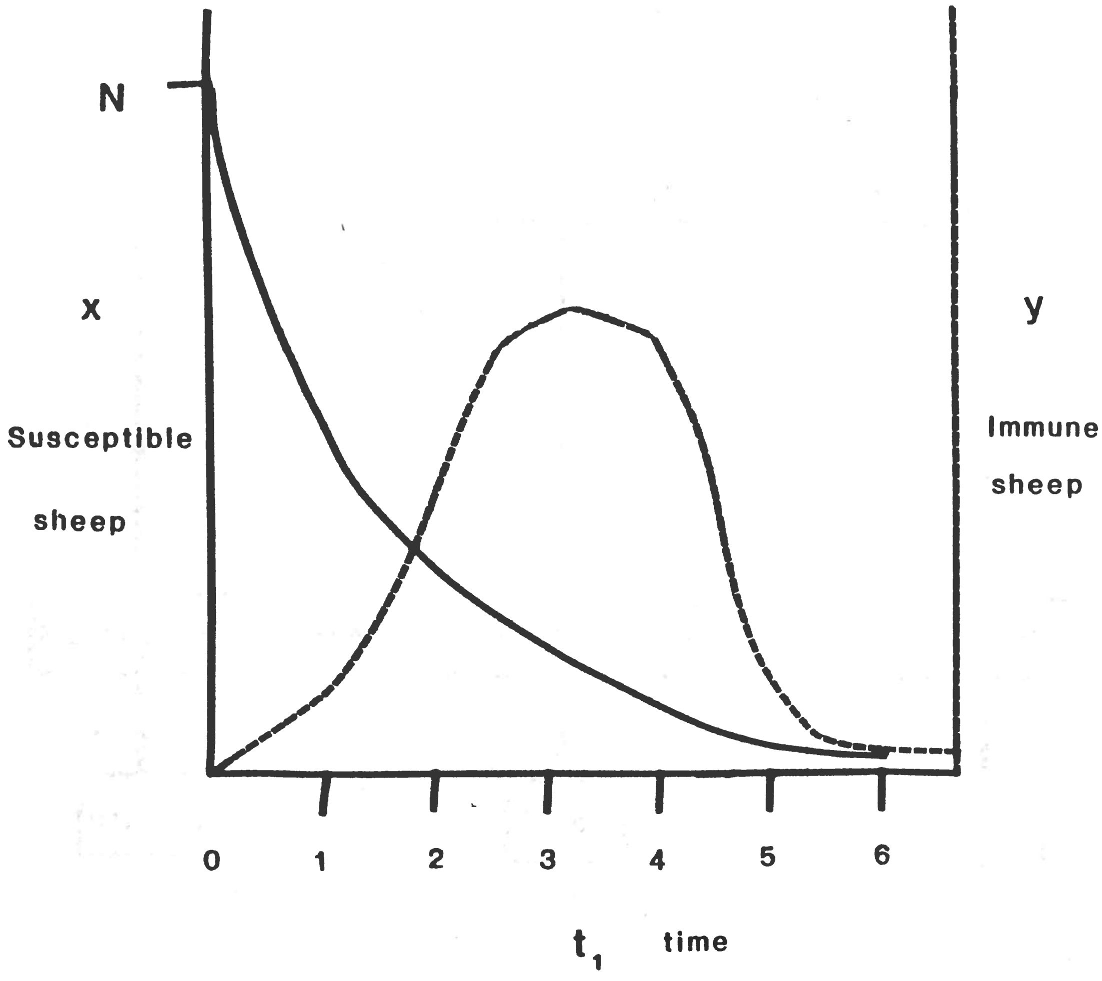


Fig. 2 Trends showing the changing number of sheep in the susceptible and immune groups in the sheep vaccination model paradigm.

whereas the numbers in the immune group rise to a peak before falling. Eventually the numbers in both groups will be zero because all animals will die unless some other control action is undertaken. Other examples of this approach are rabies in foxes (MacDonald and Bacon, 1980) and tuberculosis in badgers.

Tuberculosis in badgers: Bovine tuberculosis continues to be a problem in the south-west of England because infected badgers are a source of infection to cattle. A possible method of disease control is to reduce the badger population to a level below the threshold density for maintenance of the infection.

The dynamics of bovine tuberculosis in badgers have been investigated using a differential calculus model (Trewhella and Anderson, 1983) which includes three population states: susceptible animals, animals incubating the disease and infected animals. The links between these states are shown in the compartmental representation in Fig. 3. There is no need to include an immune state because badgers show no demonstrable immunity to bovine tuberculosis. Parameters include density dependent regulation of the badger population, natural and disease-induced death rates, the incubation period of the infection and the rate of its transmission.

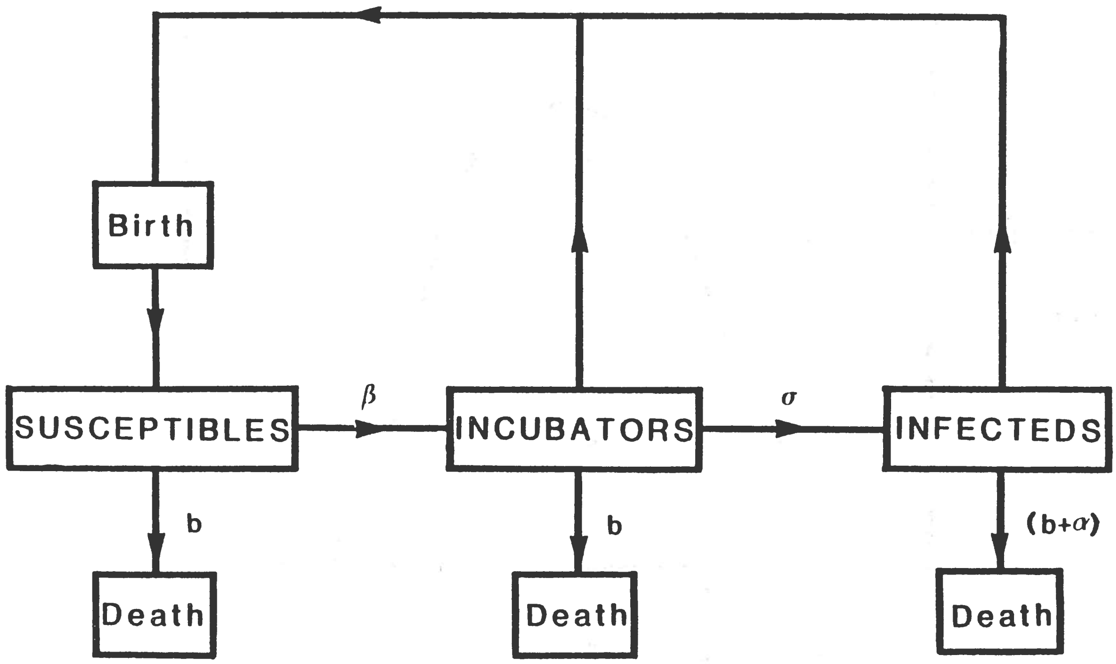


Fig. 3 Compartmental representation of badger/bovine tuberculosis model.

[From Trewhella and Anderson (1983)]

The model predicts that prevalence increases with badger density, the predicted values being supported by field observations, and that prevalence oscillations occur with a periodicity of 18 years. The model suggests that, in areas of high badger density, considerable effort would be required to control the infection.

A criticism of models based upon the differential calculus approach is the assumption that parameters do not change, for example that the survival rate of helminth eggs does not change during a season, whereas in reality climatic variation may alter survival rates from day to day. Some models do have time-dependent parameters, but this may lead to a model for which a solution is unobtainable or make the operation of the model clumsy. A major feature of such models is that they enable the long-term behaviour of the population to be studied. The population may either become extinct, or increase indefinitely, or reach a steady state. The behaviour of the population, therefore, can be investigated using the model. It is often whether or not a steady-state exists and the nature of the steady-state that is of interest, although for many infections the initial progression may be of paramount importance if economic losses are to be minimized.

Stochastic models

The models described so far are known as deterministic. The values of inputs and parameters are assumed to be known with certainty and no element of random variation is included. Alternatively, the probability of events occurring can be modelled, for example the probability of one animal infecting another. This leads to results which have a probability distribution from which means and variances can be derived. Such models are called stochastic, derived from the Greek adjective 'stochastikos' which means 'skilful in aiming at'. These models are inherently more realistic.

Stochastic exponential decay paradigm: Earlier, a deterministic model was described for the changing number of susceptibles in a population. The stochastic analogue will now be described. As before, x_t will denote the number of susceptibles in the population at time t and N the number at time 0. It is now assumed that x_t is a random variable and the probability of r susceptibles at time t is denoted by $p_r(t)$. A differential calculus approach, similar to that used in the deterministic model, can be applied to obtain an expression for the rate of change of $p_r(t)$. This rate of change, $dp_r(t)/dt$, will be influenced by flows in from the state r+1 and flows out from the state r. For state r+1 to have a flow in, there must be two events: first, there must be r+1 susceptibles at time t; secondly, one of these susceptibles must leave. The probability of these two events is $\alpha(r+1)p_{r+1}(t)$. For state r to have a flow out there must be r susceptibles at time t and one susceptible must leave. The probability of these two events is $\alpha r p_r(t)$. The instantaneous rate of change of $p_r(t)$ is therefore

$$\frac{dp_r(t)}{dt} = \alpha(r+1)p_{r+1}(t) - \alpha r p_r(t)$$

where α is a parameter.

The solution to such a differential equation may not be easily obtained but standard methods for solving are available. These methods lead to an expression for $p_r(t)$ in terms of t:

$$p_r(t) = {}^N C_r \; (1-e^{-\alpha t})^{N-r} \; e^{-\alpha t r}$$

where ${}^N C_r$ is a mathematical shorthand notation for $\frac{N!}{r!(N-r)!}$.

The "!" is read "factorial"; N! is the product of all integer numbers from 1 to N. For example $4! = 4 \times 3 \times 2 \times 1 = 24$. Therefore

$$\frac{N!}{r!(N-r)!} = \frac{N(N-1)(N-2)\ldots 3.2.1}{r(r-1)(r-2)\ldots 3.2.1.(N-r)(N-r-1)\ldots 3.2.1}$$

The expression for $p_r(t)$ is known as the time-dependent binomial probability distribution from which it can be deduced that x_t has mean (or average) value $Ne^{-\alpha t}$ and variance $Ne^{-\alpha t}(1-e^{-\alpha t})$. Comparing these results with those of the deterministic model, it can be seen that the mean value of x_t is identical to the solution obtained before. This is often, but not always, true of deterministic and stochastic models. However, an important distinction between the deterministic and stochastic model is that the latter provides a variance, therefore the extent to which population susceptible numbers fluctuate at each point in time can be deduced. Figure 4 illustrates this point, where the mean number of susceptibles at each point is shown with a confidence interval (95%) of plus and minus two standard deviations. The wider the confidence interval, the greater is the range of observed deviations from the mean number of susceptibles.

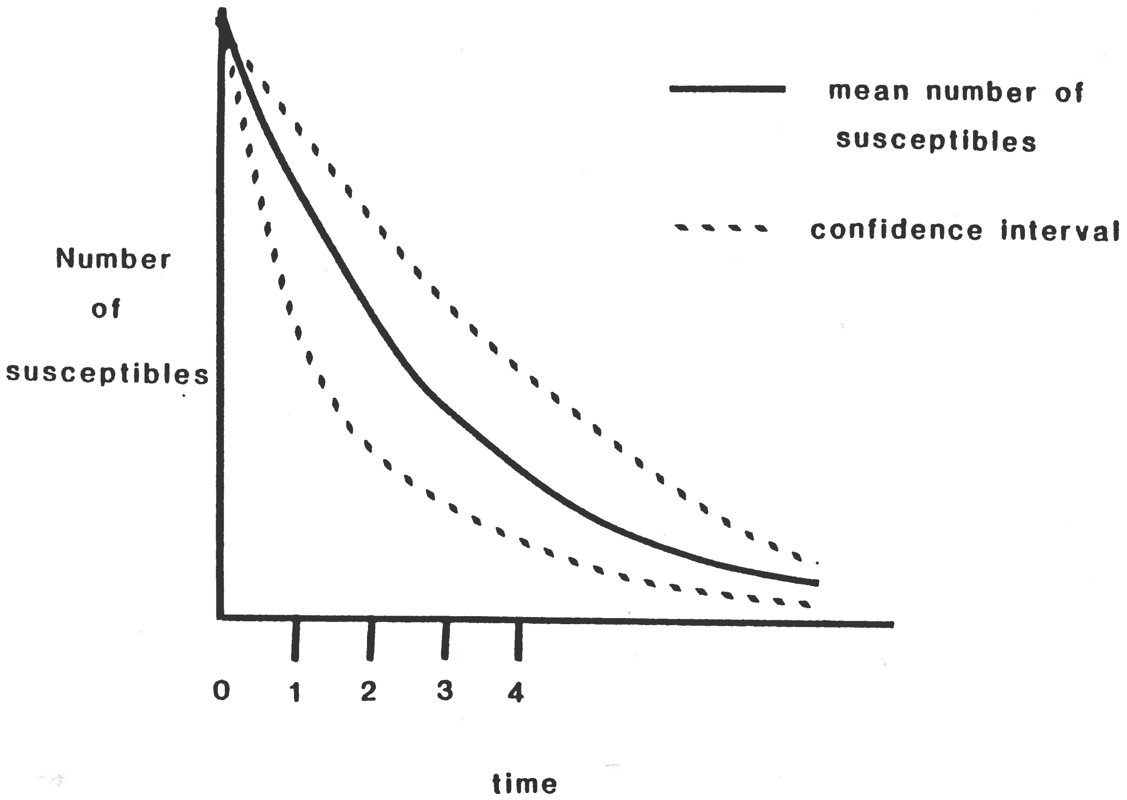


Fig. 4 Mean and confidence interval for the number of susceptibles in the stochastic exponential decay paradigm.

MODELS USING SIMULATION

In contemporary terms these models generally involve mathematics and computers. The objective is to simulate the performance of the parasite or the disease in relation to conditions which change either deterministically or randomly. Although simulation models do not always require a computer for implementation, their power and success have been closely linked to recent advances in computer technology. Many simulations undertaken to-day would have been impossible 50 years ago.

The course of many animal diseases has been studied using empirical and explanatory simulation models. Successful simulation models of these types have the potential to accurately forecast disease incidence. These forecasts are of value in selecting suitable prophylactic actions. Another important type of simulation is that which uses 'Monte-Carlo' methods. In these methods random processes are simulated using random numbers in order to decide whether or not an event takes place. This is somewhat akin to gambling hence its name.

Empirical models

Empirical models utilise indicators which are obtained by analysing the relationship between morbidity and any associated variables. A frequently used variable is climate. These models are not descriptive, because they do not attempt to analyse the dynamics of agents' life-cycles, but simply quantify associated phenomena. They are sometimes referred to as 'black-box' models because the relationship between data which are fed into the model and the results which are generated cannot be satisfactorily explained. They are particularly at risk of giving the right answer for the wrong reasons!

Fascioliasis: Fascioliasis has been modelled empirically in Britain (Gibson, 1978; Ollerenshaw, 1966; Ollerenshaw and Rowlands, 1959). The life-cycle of *F.hepatica* is complex, involving stages inside a final and intermediate host, and on herbage. Two important meteorological factors in the development of the parasite are temperatures above 10°C and the presence of free water. In the late 1950's Ollerenshaw suggested that development is therefore usually impossible during the winter (too cold) and that there may be insufficient water during some of the summer months (too dry). This is the basis of the 'M_t' forecasting system for fascioliasis. M_t is a monthly index of wetness given by

$$(R-p+5)n$$

where, on a monthly basis, R is the rainfall in inches, p is the potential transpiration and n is the number of raindays. Observations suggested that, since parasite development is also temperature-dependent, the rate of development is similar in June, July, August and September, but is halved in May and October, when the M_t index should therefore be halved.

A seasonal M_t can be calculated by adding the M_t values for the six-month period May to October. This sum simulates the progression of the disease in relation to changing meteorological conditions and so can be used to predict if animals are at risk to fascioliasis, so that suitable prophylactic measures can be undertaken. The prediction model is deterministic because no element of randomness is included in the formulation. Its simple approach enables its execution without a computer.

Similar models have been adopted for use in France (Leimbacher, 1978) and Northern Ireland (Ross, 1978).

Ovine ostertagiasis: Thomas and Starr (1978) report on an index which appears to accurately simulate the population growth of infective *O.circumcincta* larvae. These larvae accumulate during spring and summer on pasture grazed by ewes and lambs. Detailed examination of data from 1967 to 1975 suggested that the timing of peak pasture contamination depended on daily sunshine and rainfall levels. For each day, i, the number of hours of sunshine is recorded. This is scaled to give a sunshine score S_i. If the number of sunshine hours is greater than 7.9 then S_i takes the value 4, if less than 4 hours then S_i takes the value 6, otherwise S_i is 5.

Each 24h period is also divided into a day part : 9.00h to 21.00h, and a night part : 21.00h to 9.00h, during which the respective rainfall levels RD_i and RN_i are recorded. From these rainfall levels and the rainfall incidence during the previous day, the wet-day index WD_i and the wet-night index WN_i are calculated as shown in the algorithm of Fig. 5. For example, left of

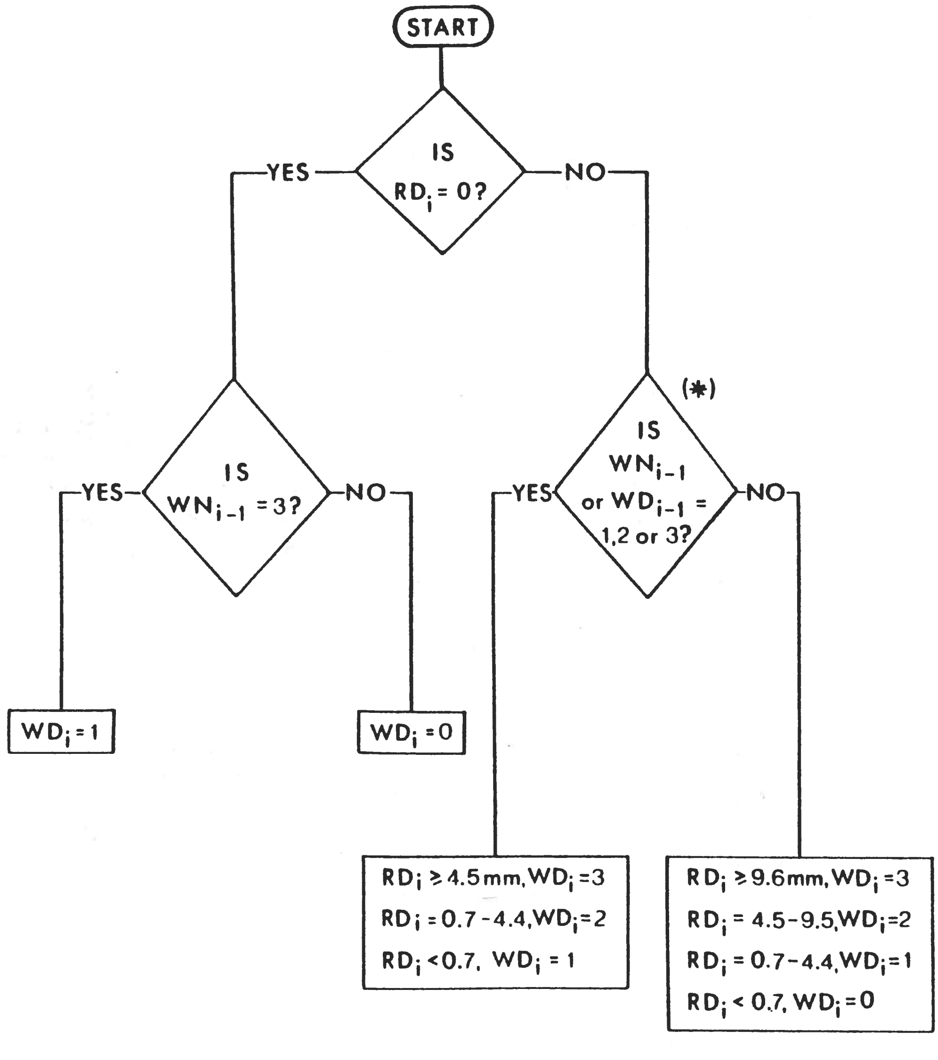


Fig. 5 Assignment of wet score values for a day period, used in the prediction of ovine ostertagiasis. (For a night period D_i and N_i are interchanged, and only WD_{i-1} considered in (*) box.)
From Gettinby and Gardiner (1980)

centre of the flowchart indicates that if the recorded rainfall level on day i is 0, the wet-day index WD_i is set equal to 1 if the wet-night index from the previous 24h period $WN_{i-1} = 3$; otherwise it takes the value 0. When RD_i is not equal to 0, the influence of the previous night and day wet indexes are shown right of centre of the flowchart. When WN_i and WD_i are determined they are summed to give the wet-day score W_i. Basically the assignations in the flow-chart give high wet-day scores to those days that are wet and are also preceded by a wet day. The wet-day scores and the sunshine scores are multiplied to give a wetness index. Peak pasture contamination levels occur when the wetness index exceeds 440.

Nematodiriasis: Attempts have also been made to predict morbidity rates of some nematode infections, using climate as an indicator (Gibson & Smith, 1978a,b; Thomas, 1978). The life-cycle of *Nematodirus* spp. is temperature-dependent. There is a correlation between soil temperature (taken 30 cm deep) and larval hatching dates. The mean soil temperature in March is used to predict the date of maximum larval count on the pasture. There is also a correlation between the estimated peak hatch date in the north-east of England and national disease severity, which can be used to predict, semi-quantitatively, national prevalence.

Explanatory models

More recently, mathematical models have been formulated which describe the dynamics of the parasite and host populations. These more refined techniques allow the course of the disease to be simulated. They include models for forecasting fluke morbidity (Hope-Cawdery et al, 1978; Williamson and Wilson, 1978), the airborne spread of foot-and-mouth disease (Gloster et al, 1981) and the occurrence of clinical ostertagiasis.

Bovine ostertagiasis: The level of pasture contamination by infective *O.ostertagi* larvae can be predicted by simulating the course of events experienced by cohorts of parasite eggs deposited on pasture (Gettinby et al, 1979). This involves estimating the proportion of eggs which proceed to the first, second and third larval stages using development fractions which quantify the rate of development of the parasite from one stage to the next according to the temperatures which it experiences. In addition, parameters associated with infectivity, fecundity and migratory behaviour of the larvae must be included.

The approach can be exemplified. Suppose a calf commences grazing on contaminated grass on April 1st. The number of infective larvae, L, ingested on April 1st can be estimated from known pasture contamination levels and the daily herbage intake of the calf. Not all larvae become established. The number of adult worms, A, to be expected in the abomasum of the calf 21 days later on April 22nd is modelled using:

$$A = (k-A_o)(1-e^{-\alpha L}) + A_o$$

where A_o is the number of adults already in the abomasum. The curve of A for different L values is sigmoidal, reflecting the assumed density-dependent relationship between larval challenge and establishment of adult worms. The parameters k and α control the rate of establishment so that the proportion established is high for low challenge levels and low for high challenge levels. The adult worms will produce eggs on April 22nd and thereafter. The number of eggs, E, produced on April 22nd is estimated from empirical data relating egg output to adult worm burden. These eggs undergo development. The time to the appearance of infective larvae is estimated by calculating from daily temperatures the fraction of development to take place each day and summing these fractions until all development has occurred n days later:

$$\frac{1}{D_1} + \frac{1}{D_2} + \ldots + \frac{1}{D_n} = 1$$

where the D's are the number of days that would be required to complete development under conditions of constant temperature. Adding n to April 22nd gives the earliest day on which the infective larvae can appear. Not all developing eggs and larvae survive and so the number of eggs that avoid mortality is the proportion, p^n, of the egg output on April 22nd. The parameter p is an estimate of the daily survival rate. If the values of n and p^n are determined for each day during which the calf grazes then it is possible to estimate the expected totals of infective larvae on pasture and the number of adult worms infecting the calf. This type of simulation requires iterative calculations which can only be performed in a reasonable time by using a computer. Not only mainframe computers but also low-cost micro-computers are suitable for this purpose. A great deal of effort has to be put into obtaining reasonable estimates of all the parameters, the pasture contamination levels when grazing commences and the meteorological data thereafter. Figure 6 shows the results of such a simulation for 6 calves which grazed on an experimental pasture from May 12th until October 1976. Pasture sampling was undertaken throughout the experiment to enable predicted and observed larval counts to be observed.

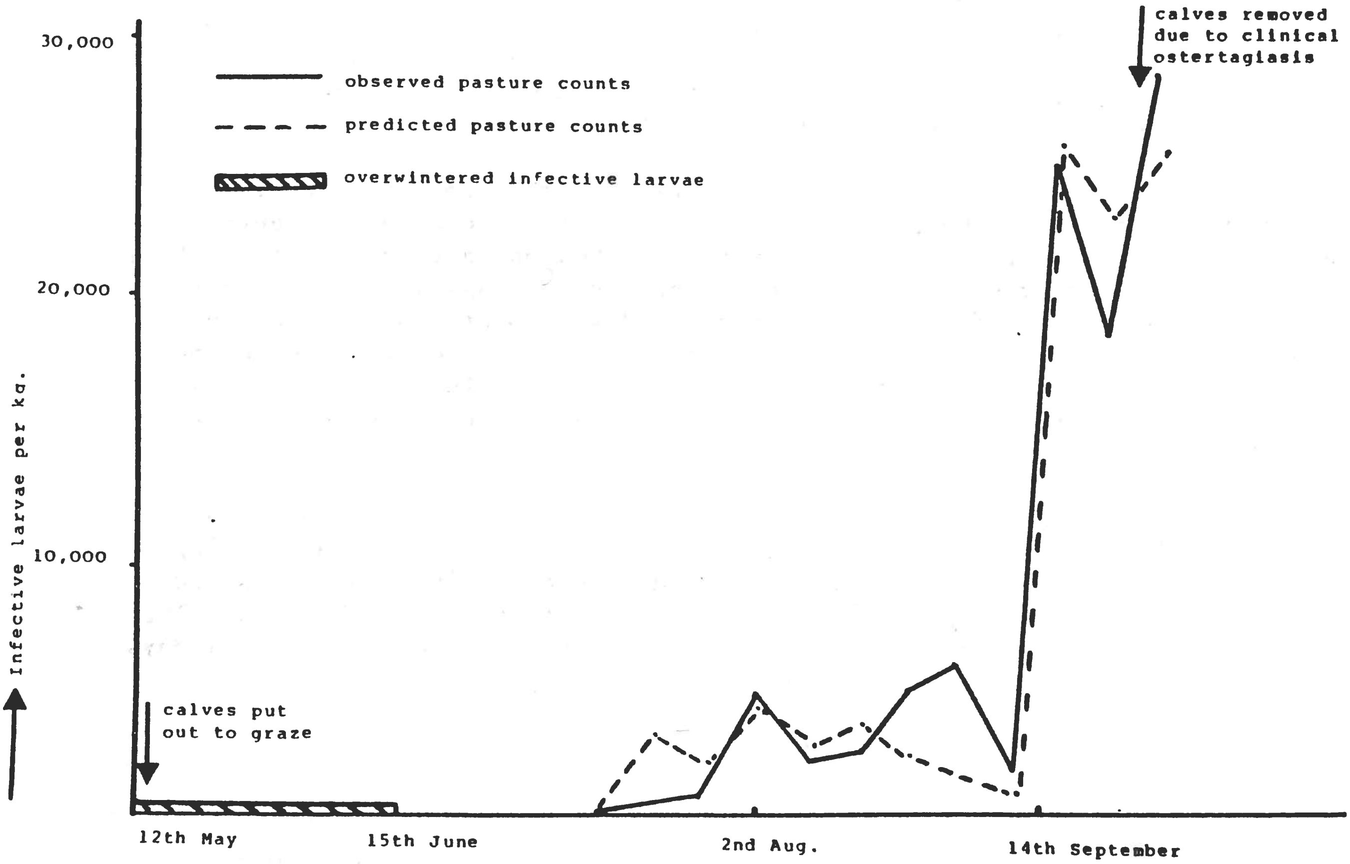


Fig. 6 Observed and predicted counts of infective *O.ostertagi* larvae on an experimental paddock during 1976.

From Gettinby et al (1979)

A prediction of herbage infective larval burdens using this type of simulation model can facilitate optimum use of anthelmintics, and movement of animals to safe pasture before challenge by large numbers of infective larvae, thereby preventing clinical ostertagiasis. A similar approach has been favourably demonstrated by Paton, Thomas and Waller (1984) for ovine ostertagiasis. This approach has also been successfully applied to tick infestations of sheep (Gardiner and Gettinby, 1983).

Monte-Carlo Methods

In many cases deterministic and stochastic models can be formulated for which no apparent solution exists. Alternatively finding of the solution may be extremely difficult or tedious. Under such circumstances simulation methods can be undertaken. Since simulation studies attempt to mimic the physical process being modelled they can be very informative and for this reason are often preferred.

Sheep tick paradigm: Suppose a model is to be formulated for the outcome of adult ticks of the species *I.ricinus* mating on the sheep host. In particular, a measure of the total number of female ticks is required so that future population numbers can be anticipated. Suppose a field study indicates that the total number of engorged ticks found on individual sheep is 0,1,2 or 3, and suppose that the respective probabilities are 4/10, 3/10, 2/10 and 1/10. The field study also suggests that male and female ticks are present in equal proportions. Using a fair ten-sided die with faces labelled 1 to 10 and a fair two-sided coin with faces labelled M for male and F for female, it is possible to simulate and obtain the number of mated female ticks on each sheep. The die is thrown and, depending on which of the sets {1,2,3,4}, {5,6,7}, {8,9} and {10} the outcome belongs to, the simulated number of adult engorged ticks on the sheep is taken to be 0,1,2 or 3 respectively. The above sets are chosen since the outcomes 0,1,2 and 3 will occur with probabilities 0.4, 0.3, 0.2 and 0.1 respectively which is consistent with the results of the field study. Suppose the outcome of the throw of the die is a 10, the simulated number of adult engorged ticks on the sheep is then 3. The coin is now tossed 3 times and the outcomes used to simulate the sex of the 3 adult engorged ticks. In the event of all 3 ticks having the same sex, that is outcomes MMM or FFF, this will lead to no mated females. All other outcomes will lead to at least one male and one female on a sheep, assuming that one male mates only with one female there will be only one mated female. Table 1 shows the possible combinations of the outcomes of the throw of the die and the coin tossing.

The procedure can be repeated for each sheep to obtain a series of 0s and 1s reflecting the outcomes of the attachment and sex distribution of the tick population on the sheep flock. To summarise the results of the simulation: the proportions of sheep with 0 and 1 mated females could be reported. The simulation could also be used to test the effects of different assumptions on the outcomes. For example, if the ratio of male to female ticks was no longer 1:1 but biased towards females, in the ratio 1:2, then the study could be repeated using a biased coin that would give an M outcome with probability 1/3 and a F outcome with probability 2/3 when tossed. Similarly, if it was thought that male ticks could mate with several females, then the simulation could be repeated. If, for example, attachment led to the combination of one male and two female ticks on a sheep, then this would produce 2, rather than 1, mated females.

Table 1. Possible number of mated female ticks on one sheep, resulting from simulated attachment and sex distribution of tick population.

Outcome from One Throw of Ten-sided Die	Simulated Number of Engorged Ticks on a Sheep	Simulated Sex Distribution of Engorged Ticks from Coin Tosses	Number of Mated Females
{1,2,3,4}	0	-	0
{5,6,7}	1	M	0
		F	0
{8,9}	2	MM	0
		MF	1
		FF	0
		FM	1
{10}	3	MMM	0
		MMF	1
		MFM	1
		FMM	1
		FFF	0
		FMF	1
		MFF	1

In modern simulation studies the computer takes over the role of the die and the coin. The results from these 'lotteries' can be produced using a <u>random number generator</u>. For example, to replace the 10-sided die, the computer could be instructed to produce integer numbers from 1 to 10 in random order such that a large series of generated numbers would produce each number in equal proportions.

<u>Sheep tick control</u>: A more exacting study of the dynamics of the life-cycle of the sheep tick is described by Plowright and Paloheimo (1977). These authors use Monte-Carlo simulation to investigate the behaviour of a stochastic model proposed for the incidence of mating. Field investigations (Milne, 1950) revealed that tick occurrence was patchy : a pasture may have a heavy burden whereas an adjacent field separated from the first only by a fence may have no ticks. This suggested that ticks have problems with effective dispersal. One reason may be that, at low densities, tick population growth is inhibited by a low rate of mating. The model proposed makes several assumptions : that each adult only mates if it encounters an individual of the opposite sex on the sheep to which it is attached; that each adult only mates once; that each tick has an equal probability of attaching to a sheep; that all ticks have an equal probability of encountering one another. The last two assumptions are dubious but do not affect the model appreciably. The total number of matings at various sheep densities, and with varying numbers of ticks on each sheep, can be estimated based upon the Poisson distribution. Computer random number generation is used to determine : first, whether or not a tick becomes attached and secondly, which sheep the tick becomes attached to if

attachment takes place. By including a rate of survival in the model, it is possible to predict the growth rate of the tick population for different levels of tick population size and sheep density. When the sheep population is low, the rate of tick population increase is insensitive to changes in the size of the tick population, but highly sensitive to changes in the size of the sheep population. Conversely, when the tick population is low, the rate of tick population increase is relatively insensitive to changes in sheep numbers, but sensitive to changes in tick numbers. This supports the hypothesis that it is difficult for ticks to establish themselves in new pastures. It also suggests that a reduction in host density may not be an effective means of controlling tick infestation, because the rate of tick population increase does not always depend on sheep density. The model also predicts that extinction of the tick population takes place over a narrow range of tick population sizes corroborating field observations of patchy tick distribution.

Fascioliasis control: Liver-fluke disease can be controlled by the use of molluscicides and anthelmintics. The molluscicides reduce the density of snails in their habitat and therefore decrease the chances of miracidia locating a snail host when they disperse from eggs in the faeces. The anthelmintics are effective in killing off the immature and mature flukes and so reduce the number of eggs in the faeces. Gettinby (1974) used Monte-Carlo simulation to compare the effects of molluscicides and anthelmintics on the rate at which miracidia penetrate the snail host. Random number generation was used to determine the position of each snail in a field and the position of each miracidium to emerge from a faecal locus. The number of miracidia to encounter each snail was determined by counting the number of miracidia to come within a 15cm chemotactic radius of a snail. Not all miracidia successfully penetrate the snail and so, from the number of encounters, a random number generator determined the number of miracidia to be absorbed by each snail. These simulations were repeated many times in order to be representative. To assess the effects of molluscicides and anthelmintics various snail densities were considered. The results are shown in Fig. 7 and Fig. 8. Figure 7 demonstrates that the reduction of the snail population by the use of a molluscicide produces a proportional reduction in the penetration rate of the miracidia. However, because the graph in Fig. 8 reaches a plateau as the parasite number increases, if anthelmintics are to reduce the penetration rate of the miracidia then they must have a high efficacy, otherwise their effect is only marginal.

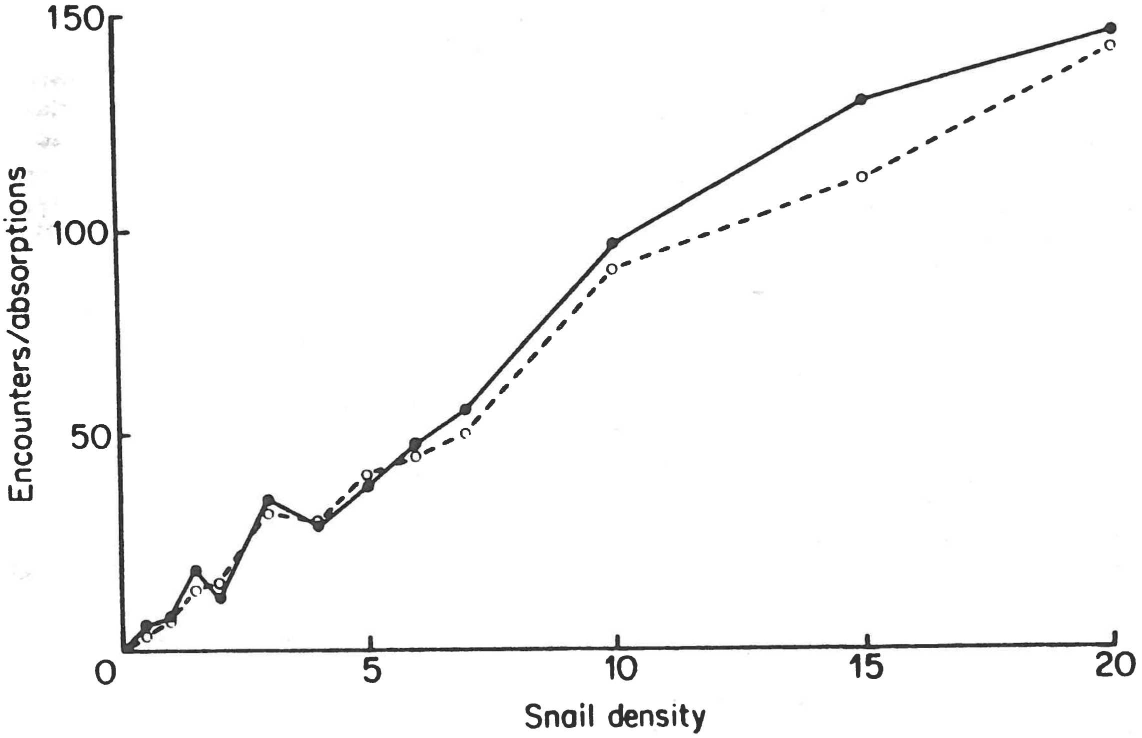


Fig. 7 Snail penetration rates by miracidia for different snail densities (m^{-2}).
[From Gettinby (1974)]

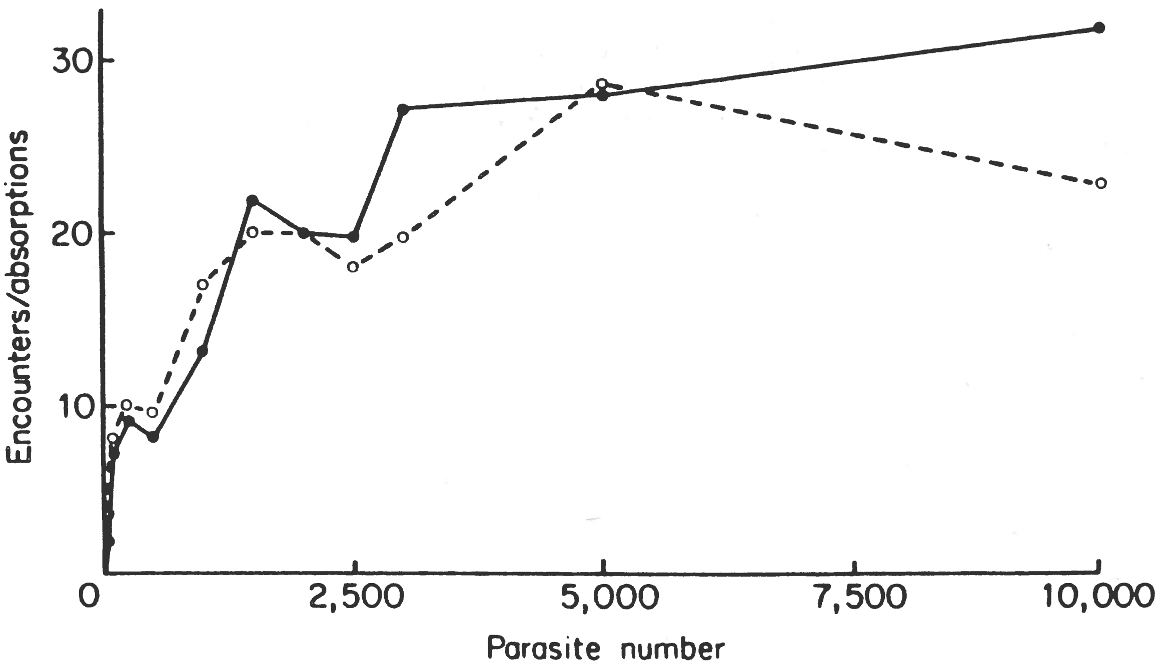


Fig. 8 Snail penetration rates by miracidia for different intensities of miracidia in the faeces.
[From Gettinby (1974)]

MODELS USING MATRICES AND NETWORKS

Matrix and network methods share a great deal of similarity. The use of matrices to describe population changes became firmly established when Leslie (1945) published his celebrated Leslie matrix. In contrast, network models, although extensively exploited by control engineers, have been largely overlooked in the life sciences, with some exceptions (Lewis, 1977). Often the same problem can be formulated using a network and a matrix approach. The network formulation is particularly attractive when time delays are a feature of the life-cycle being modelled and when the output response of a biological system is to be measured for a given input. On the other hand matrix formulations are attractive when the behaviour of several states of a population is of interest at successive points in time.

Matrix models

Matrices often take the form of a rectangular array containing numbers of hosts or of parasites in a defined state or stage of development known as the state vector, or containing reproduction and survival rates of hosts or parasites in different states or stages known as the transition matrix. In this way it is possible to obtain the state of the system from one point in time to another.

Fascioliasis: The life-cycle of *F. hepatica* will be used to illustrate the formulation of a simple matrix model. The parameters have been estimated from field studies. It is assumed that eggs from the adult fluke develop to miracidia after 4 weeks, miracidia which penetrate the molluscan host, *L. truncatula*, develop and emerge as metacercariae 8 weeks later, and that the metacercariae can survive up to 3 weeks before desiccation. The weekly survival rates of the adult flukes, the developing eggs, the intra-molluscan stages and the metacercariae are 0.95, 0.3, 0.5 and 0.8 respectively. Each adult fluke is assumed to produce 2500 eggs weekly, and each miracidium to penetrate a snail with probability 0.005. The phases of development in the snail are simplified by labelling all of the asexual stages s. It is also assumed that reproduction occurs in the last intra-molluscan stage when the fecundity is 4.3. A further simplification is that each metacercaria in each week of development has probability 0.02 of becoming an adult worm. Let a be the number of adult flukes and e_i, c_i and m_i be the number of eggs, cercariae and metacercariae respectively in the ith week of development. The number of adult flukes from week t to week t+1 will be those adults in week t that survive plus those metacercariae which are ingested and become established:

$$a(t+1) = 0.95a(t) + 0.02m_3(t).$$

The number of eggs at time (t+1) in the first week of development will be those produced by adults in the previous week:

$$e_1(t+1) = 2500a(t).$$

The number of eggs at time t+1 in the second week of development will be those surviving from the previous week:

$$e_2(t+1) = 0.3e_1(t).$$

The change from week to week of all the stages can conveniently be summarised in matrix form,

$$
\begin{bmatrix} a \\ e_1 \\ e_2 \\ e_3 \\ e_4 \\ s_1 \\ s_2 \\ s_3 \\ s_4 \\ s_5 \\ s_6 \\ s_7 \\ s_8 \\ m_1 \\ m_2 \\ m_3 \end{bmatrix}_{t+1} =
\begin{bmatrix}
0.95 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.02 & 0.02 & 0.02 \\
2500 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.3 & 0 & \cdot & \cdot & & & & & & & & & & \cdot & 0 \\
\cdot & & 0.3 & & & & & & & & & & & & & \\
\cdot & & & 0.3 & & & & & & & & & & & & \\
 & & & & 0.002 & & & & & & & & & & & \\
 & & & & & 0.5 & & & & & & & & & & \\
 & & & & & & 0.5 & & & & & & & & & \\
 & & & & & & & 0.5 & & & & & & & & \\
 & & & & & & & & 0.5 & & & & & & & \\
 & & & & & & & & & 0.5 & & & & & & \\
 & & & & & & & & & & 0.5 & & & & & \\
 & & & & & & & & & & & 0.5 & & & & \\
\cdot & & & & & & & & & & & & 4.3 & & & \\
\cdot & & & & & & & & & & & & & 0.8 & & \cdot \\
0 & \cdot & \cdot & & & & & & & & & & & & 0.8 & 0
\end{bmatrix}
\begin{bmatrix} a \\ e_1 \\ e_2 \\ e_3 \\ e_4 \\ s_1 \\ s_2 \\ s_3 \\ s_4 \\ s_5 \\ s_6 \\ s_7 \\ s_8 \\ m_1 \\ m_2 \\ m_3 \end{bmatrix}_{t}
$$

In shorthand notation this is written

$$\underline{x}_{t+1} = \underline{P}\underline{x}_t$$

where $\underline{x}_t$ and $\underline{x}_{t+1}$ are the state vectors and correspond to times t and t+1, and $\underline{P}$ is the transition matrix. Characters are underlined to denote a matrix. Note that to retrieve the first equation, the first element in the state vector (a_{t+1}) is equated with the sum, after the first row of the transition matrix has been turned on its side and each element of this row multiplied by the corresponding elements of the state vector $\underline{x}_t$. Other relationships are similarly retrieved. For example, if the number of metacercereariae in the first week of development at time t+1 are required, then the row transition matrix corresponding to this element is turned on its side and corresponding elements in $\underline{x}_t$ multiplied to give

$$m_1(t+1) = 4.3s_8(t).$$

The matrix model proposed for the life-cycle of *F. hepatica* is similar to that proposed by Leslie (1945) for populations in general. Leslie suggested that members of a population can be divided into exclusive age classes of fixed duration, so that every member of a class faces the same probability of surviving and the same probability of reproducing. If the vector containing the number in each class during a certain time interval is multiplied by the Leslie matrix describing the population dynamics, then the vector containing the number in each class during the following time interval is obtained. For example, if there are k age classes:

$$\begin{bmatrix} n_1 \\ n_2 \\ n_3 \\ \cdot \\ \cdot \\ n_{k-1} \\ n_k \end{bmatrix}_{t+1} = \begin{bmatrix} f_1 & f_2 & \cdots & f_{k-1} & f_k \\ p_1 & 0 & \cdots & 0 & 0 \\ 0 & p_2 & \cdots & 0 & 0 \\ \cdot & & & \cdot & \cdot \\ \cdot & & & \cdot & \cdot \\ \cdot & & & \cdot & \cdot \\ 0 & 0 & \cdots & p_{k-1} & 0 \end{bmatrix} \begin{bmatrix} n_1 \\ n_2 \\ n_3 \\ \cdot \\ \cdot \\ n_{k-1} \\ n_k \end{bmatrix}_{t}$$

where $n_i(t+1)$ is the number in the ith class at time t+1, and f_i and p_i are respectively the fecundity and survival rates for age class i.

The advantage of the matrix approach is that once $\underline{P}$ and the number of the state vector at time 0 are known then the population sizes at any future time can be predicted. For example, the population numbers after 4 units of time could be obtained from the successive calculations

$$\underline{x}_1 = \underline{P}\underline{x}_o$$
$$\underline{x}_2 = \underline{P}\underline{x}_1$$
$$\underline{x}_3 = \underline{P}\underline{x}_2$$
$$\underline{x}_4 = \underline{P}\underline{x}_3$$

The matrix equations described above have many interesting properties from which the salient features of the population can be investigated. Details of these are given by Leslie (1945). A more realistic matrix representation of the life-cycle of *F. hepatica* is discussed by Gettinby and McClean(1979). This is a state-transition model with five states: mature flukes (in sheep), eggs (on grass), rediae (in snails), metacercariae (on grass), immature flukes (in sheep). A mortality rate is attached to all stages, and fecundity to the adult fluke and redia, which reproduce sexually and asexually respectively. The matrix includes probabilities of transition from one stage to the next, and fecundity, based upon available field data.

The first part of the model describes the natural infection in sheep in Britain and Ireland. The second part investigates and compares various control strategies: the use of flukicides, molluscicides and land drainage. There are three conclusions. Molluscicides are most effective when applied in early spring. Flukicides eradicate the infection when given monthly and control it when given at two-monthly intervals; if dosing is only annual, then it is best given in August. Good drainage is an effecitve means of control. Again, the model only indicates possible outcomes, in the absence of accurate field data to support the values of the input parameters in the model.

Network models

The inability of many other models to cope with changing inputs during the period of operation of the model, can be circumvented using a network representation of a parasite's life-cycle. Some elementary examples will demonstrate the symbolism used in this approach.

Protozoal paradigm: Consider a population of identical protozoa which reproduce by binary fission. A constant T units of time occurs between successive fissions. The probability that any one protozoon survives this time is p. To construct the network shown in Fig. 9, which represents the life-cycle, consider the flow of newly formed protozoa in the population. After a time delay, T, only a proportion, p, of these survives. This results in the flow after the time delay being scaled by a factor p. This is immediately succeeded by fission which results in the flow doubling and so a further scaling by a factor 2 is required. The network convention is to denote time delays by squares and scaling parameters by circles. Since the products of fission are newly formed cells, this flow is connected back into the time delay. This is a very simple network and consists of one loop and no alternative paths.

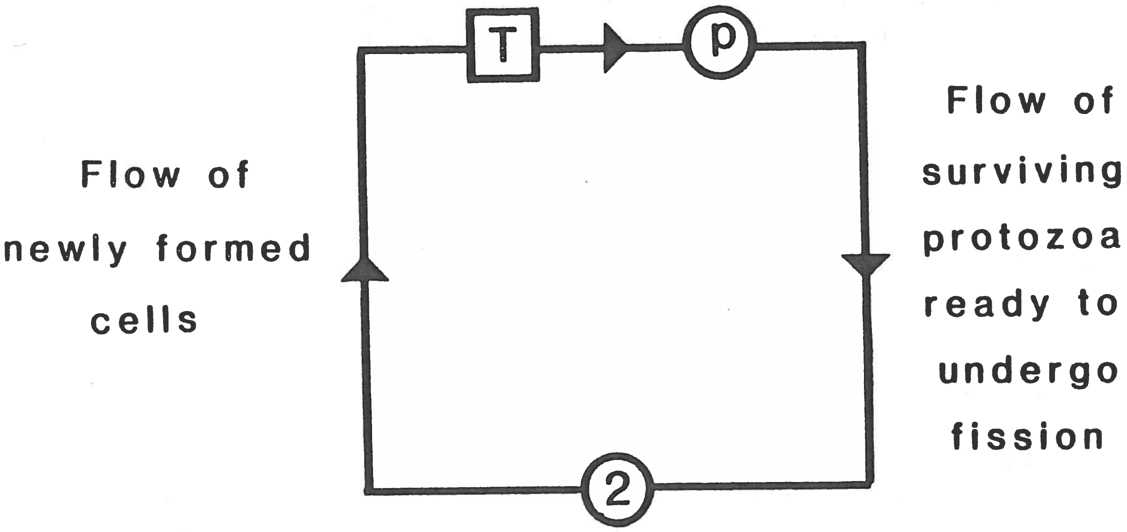


Fig. 9 Network representation in the protozoal paradigm.

Ostertagiasis: Another network will now be described for the summer life-cycle of *O. ostertagi*, one of the parasites responsible for outbreaks of parasitic gastroenteritis in cattle. The network is shown in Fig. 10. The unit of time is 1 week. The parameters have been estimated from field studies. Starting with the flow of eggs which have been passed in the faeces of the calf, these eggs undergo a time delay of 3 weeks before the infective L_3 larvae appear. The proportion to survive during this period is assumed to be 0.27. During the following week these L_3 larvae either become ingested by the calf with probability 0.28 or accumulate on the pasture with probability 0.72. Those that accumulate are delayed for a week, during which their survival rate is 0.87, before joining the flow of new infective larvae. The L_3 larvae that were ingested are delayed for 3 weeks before reaching the adult egg-laying stage. Only the proportion 0.29 of these become established as adults of which 0.5 will be females. These females reproduce at a rate of 1100 eggs per week. From successive egg cohorts, female adults will accumulate from week to week. To facilitate the accumulation, the existing females must enter a feedback loop in which the weekly survival rate is 0.70 and which connects them with the flow of new female adult worms in the calf. The network therefore consists of a forward loop and two feedback loops. When the model is operated Fig. 11 shows how the total flow of adult female worms behaves over a 17-week period if only one fertilized female adult worm is present in week 1. The population does not start to grow dramatically until the calf has been grazing for 12 weeks.

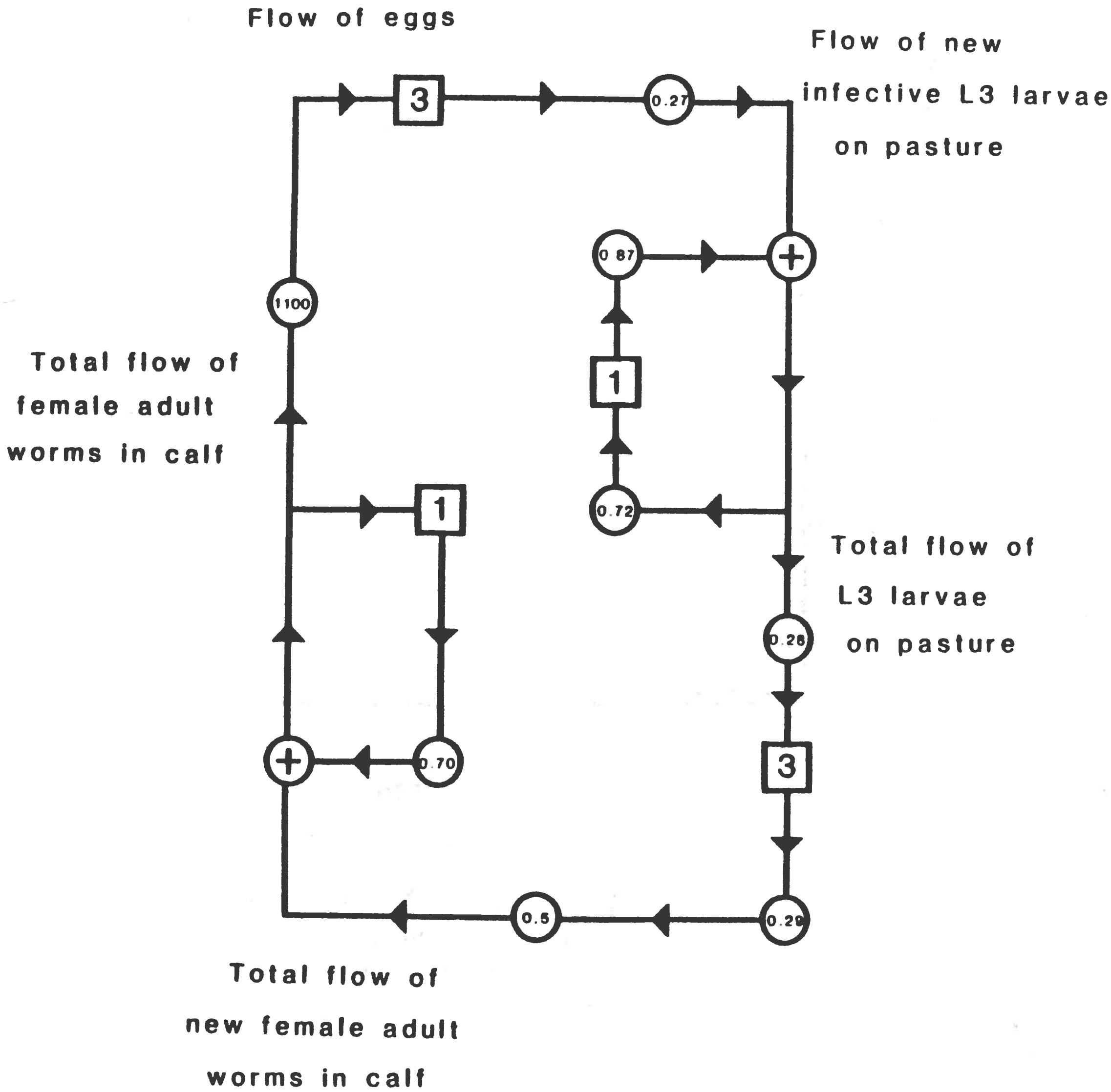


Fig. 10 Network representation of the summer life-cycle of *O. ostertagi*.

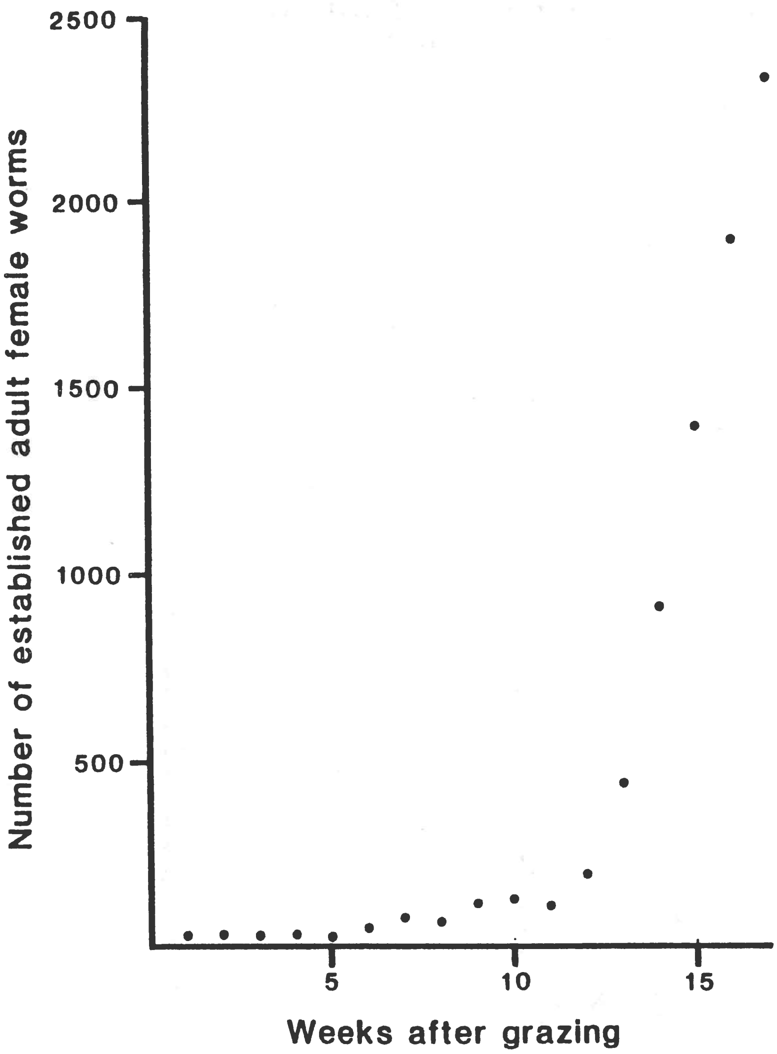


Fig. 11 Total flow of adult female worms resulting from one adult female in week 1 in the network model of *O. ostertagi*.

A similar type of network is shown in Fig. 12 for the life-cycle of *O. circumcincta* and was used by Paton and Gettinby (1983) in the study of ovine ostertagiasis. Three inputs X,Y and Z are shown corresponding to infective larvae from ewes, lambs and overwintered pasture contamination. The scalar parameters a,b and d refer to the weekly survival rates of developing eggs, infective larvae on pasture and adult worms. The remaining scalar parameters c and e correspond to the weekly ingestion rate of infective larvae and the fecundity of adult worms.

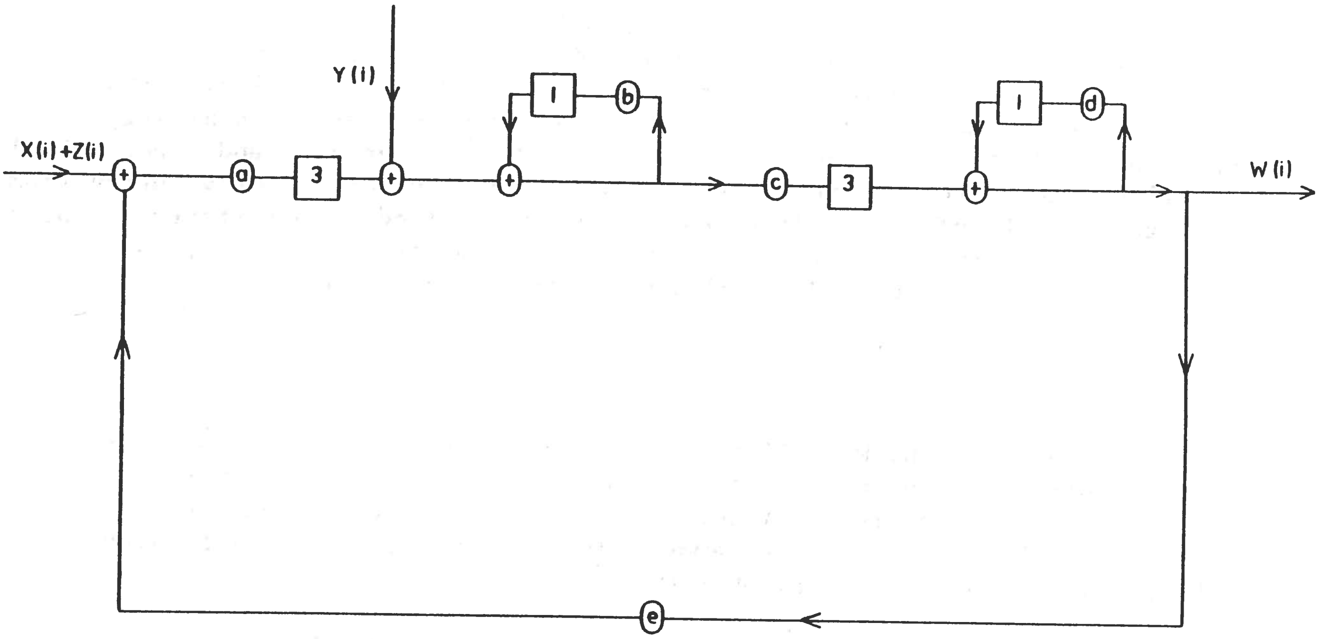


Fig. 12 Network representation of the life-cycle of *O.circumcincta*.

[From Paton and Gettinby (1983)]

The effects of various anthelmintic strategies can be investigated by altering components of the network which will be affected by the particular strategy. For example, dosing of lambs will reduce the lamb egg input (Z) and dosing of ewes will decrease the ewe egg input (X). The simulation suggests that regular dosing of lambs at four-weekly intervals for the first six months of life is very effective. Similarly, dosing lambs three times in July and August is effective. The single administration of an anthelmintic to ewes at lambing time is the least effective of the anthelmintic strategies.

DISCUSSION

This paper has described some modelling techniques, with examples from studies of infectious diseases - mainly of helminth infections. 'Modelling' now has a broad remit, including the conceptual representation of any real event in mathematical terms. Models have been developed for the choice of disease control strategies, for example for brucellosis in the United Kingdom

(Hugh-Jones, et al, 1976) and in the United States (Dietrich, Amosson and Hopkin, 1980). They have been used to investigate diseases of uncertain aetiology, for example epizootic bovine abortion (Lehenbauer and Harman, 1982). Models have also been designed which assess the cost of disease and its control; some of these have been reviewed by Beal and McCallon (1983).

Modelling is offered neither as a theoretical exercise for self-indulgent mathematicians nor as the panacea for current veterinary problems. It is one component of the epidemiological approach. It can not be used effectively without reliable field- and experimentally-derived data relating to diseases' natural history. The danger of applying modelling in isolation from traditional field observation has been noted recently, both in human epidemiology - in the context of a re-appraisal of Snow's classical investigation of cholera (Cameron and Jones, 1983) - and in veterinary epidemiology (Hugh-Jones, 1983). When used in association with diagnostic and experimental disciplines, modelling can increase understanding of disease. Originating from investigations of infectious diseases, it is now applied to multifactorial herd problems, and, in the future, using modern microcomputer technology, may become part of intensive herd health and productivity schemes.

REFERENCES

Beal, V.C. and McCallon, W.R. (1983). The use of mathematical models in animal disease program evaluation. In: Proceedings of the Third International Symposium on Veterinary Epidemiology and Economics. Arlington, Virginia, 6-10 September 1982. Veterinary Medical Publishing Company, Edwardsville. pp. 400-407.

Brownlee, J. (1915). Historical note on Farr's theory of the epidemic. Br. Med. J. 2, 250-252.

Cameron, D. and Jones, I.G. (1983). John Snow, the Broad Street pump and modern epidemiology. Int. J. Epidemiol. 12, 393-396.

Dietrich, R.A., Amosson, S.H. and Hopkin, J.A. (1980). Epidemiologic and Economic Analysis of the USA Bovine Brucellosis Program and Selected Program Alternatives via an Open Ended Simulation Model. In: Geering, W.A., Roe, R.T. and Chapman, L.A. (eds.). Veterinary Epidemiology and Economics. Proceedings of the Second International Symposium on Veterinary Epidemiology and Economics. Canberra, 7-11 May 1979. Australian Government Publishing Service, Canberra. pp. 623-632.

Frost, W.H. (1976). Some conceptions of epidemics in general. Am. J. Epidemiol. 103, 141-151.

Gardiner, W.P. and Gettinby, G. (1983). A weather-based prediction model for the life-cycle of the sheep tick Ixodes ricinus L. Vet. Parasitol. 13, 77-84.

Gettinby, G. (1974). Assessment of the effectiveness of control techniques for liver fluke infection. In: Ecological Stability. Ed. Usher and Williamson. Chapman and Hall.

Gettinby, G., Bairden, K., Armour, J. and Benitez-Usher, C. (1979). A prediction model for bovine ostertagiasis. Vet. Rec. 105, 57-59.

Gettinby, G. and Gardiner, W.P. (1980). Disease incidence forecasts by means of climatic data. Biometeorology. 7, 87-103.

Gettinby, G. and McClean, Sally (1979). A matrix formulation of the life-cycle of liver fluke. Proc. R. Ir. Acad. 79 B, 155-167.

Gibson, T.E. (1978). The 'Mt' system for forecasting the prevalence of fascioliasis. In: Weather and Parasitic Animal Disease. W.M.O. Technical Note No. 159. pp. 3-5.

Gibson, T.E. and Smith, L.P. (1978a). Forecasting the prevalence of nematodiriasis in England and Wales. In: Weather and Parasitic Animal Disease, pp. 74-75. W.M.O. Technical Note No. 159.

Gibson, T.E. and Smith, L.P. (1978b). Forecasting outbreaks of parasitic gastro-enteritis in ruminants in England and Wales. In: Weather and Parasitic Animal Disease, pp. 76-77. W.M.O. Technical Note No. 159.

Gloster, J., Blackall, R.M., Sellers, R.F. and Donaldson, A.I. (1981). Forecasting the airborne spread of foot-and-mouth disease. Vet. Rec. 108, 370-374.

Greenwood, Major (1943). Medical statistics from Graunt to Farr. VI. Some English medical statisticians in the Eighteenth Century. Biometrika 33, 1-24.

Hope-Cawdery, M.J., Gettinby, G. and Grainger, J.N. (1978). Mathematical models for predicting the prevalence of liver-fluke disease and its control from biological and meteorological data. In: Weather and Parasitic Animal Disease. W.M.O. Technical Note No. 159. pp. 21-38.

Hugh-Jones, M. (1983). Conclusions for the symposium and lessons for the future. In: Proceedings of the Third International Symposium on Veterinary Epidemiology and Economics. Arlington, Virginia, 6-10 September 1982. Veterinary Medical Publishing Company, Edwardsville. pp. 650-654.

Hugh-Jones, M.E., Ellis, P.R. and Felton, M.R. (1976). The use of a computer model of brucellosis in the dairy herd. In: Ellis, P.R., Shaw, A.P.M. and Stephens, A.J. (eds.) New Techniques in Veterinary Epidemiology and Economics. Proceedings of a symposium, University of Reading, July 12-15 1976. pp. 96-112.

Lehenbauer, T. and Harman, B. (1982). Statistical modelling of real world health problems with an electronic spreadsheet program. In: Symposium on Computer Applications in Veterinary Science. Mississippi State University, Starkville, October 13-15 1982. pp. 519-530.

Leimbacher, F. (1978). Experience with the 'Mt' system of forecasting fascioliasis in France. In: Weather and Parasitic Animal Disease. W.M.O. Technical Note No. 159. pp. 6-13.

Leslie, P.H. (1945). On the use of matrices in certain population mathematics. Biometrika 35, 183-212.

Lewis, E.R. (1977). Network models in population biology. Springer-Verlag, Berlin.

Macdonald, D.W. and Bacon, D.W. (1980). To control rabies: vaccinate foxes. New Scientist 87, 640-645.

Milne, A. (1950). The ecology of the sheep tick, *Ixodes ricinus* (L.). Spatial distribution. Parasitology 41, 189-207.

Ollerenshaw, C.B. (1966). The approach to forecasting the incidence of fascioliasis over England and Wales, 1958-1962. Agric. Meteorol. 3, (1/2), 35-54.

Ollerenshaw, C.B. and Rowlands, W.T. (1959). A method of forecasting the incidence of fascioliasis in Anglesey. Vet. Rec. 71, 591-598.

Paton, G. and Gettinby, G. (1983). The control of a parasitic nematode population in sheep represented by a discrete time network with stochastic inputs. Proc. R. Ir. Acad. 83B, 267-280.

Paton, G., Thomas, R.J. and Waller, P.J. (1984). A prediction model for parasitic gastro-enteritis in lambs. Int. J. Parasitol. In press.

Plowright, R.C. and Paloheimo, J.E. (1977). A theoretical study of population dynamics in the sheep tick. Theor. Pop. Biol. 12, 286-297.

Ross, J.G. (1978). Stormont 'wet day' fluke forecasting. In: Weather and Parasitic Animal Disease. W.M.O. Technical Note No. 159, pp. 14-20.

Takizawa, T., Ito, T. and Kosuge, M. (1977). Prototype of simulation models for epizootics in domestic animals. Nat. Inst. Animal Hlth. Quarterly 17, 171-178.

Thomas, R.J. (1978). Forecasting the onset of nematodiriasis in sheep. In: Weather and Parasitic Animal Disease, pp. 68-73. W.M.O. Technical Note No. 159.

Thomas, R.J. and Starr, J.R. (1978). Forecasting the peak of gastrointestinal nematode infection in lambs. Vet. Rec., 103, 465-468.

Trewhella, W.J. and Anderson, R.M. (1983). Modelling bovine tuberculosis. In: Thrusfield, M.V. (ed.) Society for Veterinary Epidemiology and Preventive Medicine. Proceedings of a meeting held at the University of Southampton on 12th and 13th of April 1983. pp. 78-84.

Williamson, M.H. and Wilson, R.A. (1978). The use of mathematical models for predicting the incidence of fascioliasis. In: Weather and Parasitic Animal Disease. W.M.O. Technical Note No. 159. pp. 39-48.

OPEN SESSION

STUDIES ON THE EPIDEMIOLOGY OF ACUTE BABESIOSIS IN IRELAND

BY

J.S. GRAY and G. LOOBY*

In a study on bovine babesiosis in an area serviced by a veterinary practice in Oldcastle, Co. Meath it became evident that the veterinary surgeons were encountering an increasing number of acute or unresponsive cases. This was reflected in increased numbers of revisits and blood transfusions (Gray, Fitzgerald & Strickland, 1983). In an attempt to determine how widespread this trend is and also to provide an explanation for it surveys were conducted locally amongst farmers and nationally amongst veterinary surgeons.

MATERIALS AND METHODS

Veterinary practice survey

Information was sought from veterinary surgeons throughout the country in an attempt to determine how widespread the increased prevalence of acute cases had become and the opinion of veterinary surgeons as to the underlying causes of the trend was sought. This survey also provided an opportunity to assess the economic importance of the disease in the country.

The information was obtained by circulating questionnaires, and by direct contact. In the first instance a quarter of the vets. registered in each county were circulated. Subsequently, when all returns had been obtained additional contacts were made to fill in gaps. A total of 160 veterinary practices were contacted. A supplementary questionnaire was circulated to 40 vets. that replied to the first contact.

Farm Survey

Farmers that received visits from the Oldcastle practice veterinary surgeons to treat babesiosis cases in 1982 (274) were circulated and questions asked that were mainly designed to determine whether there was an increasing tendency to call the vet. to cases in advanced stages of the disease. Other factors such as land usage and stock origin were also covered. For purposes of analysis replies were divided into those that experienced one or more acute or unresponsive cases in 1982 (a-c farms) and those that did not (na-c farms).

RESULTS

Veterinary practice survey

Out of the 160 veterinary practices contacted 71 (46%) returns were made.

* Department of Agricultural Zoology & Genetics, University College, Dublin.

The majority of practices were of the opinion that acute cases had become more prevalent in the past 15 years (Table 1) and this phenomenon seems to be widespread throughout the country (Fig. 1).

Table 1. Prevalence of babesiosis in veterinary practices in Irish Republic.

Average annual number cases per practice	148
Percent practices with increasing prevalence of acute cases.	64.0
Average percent acute cases per practice	25.0

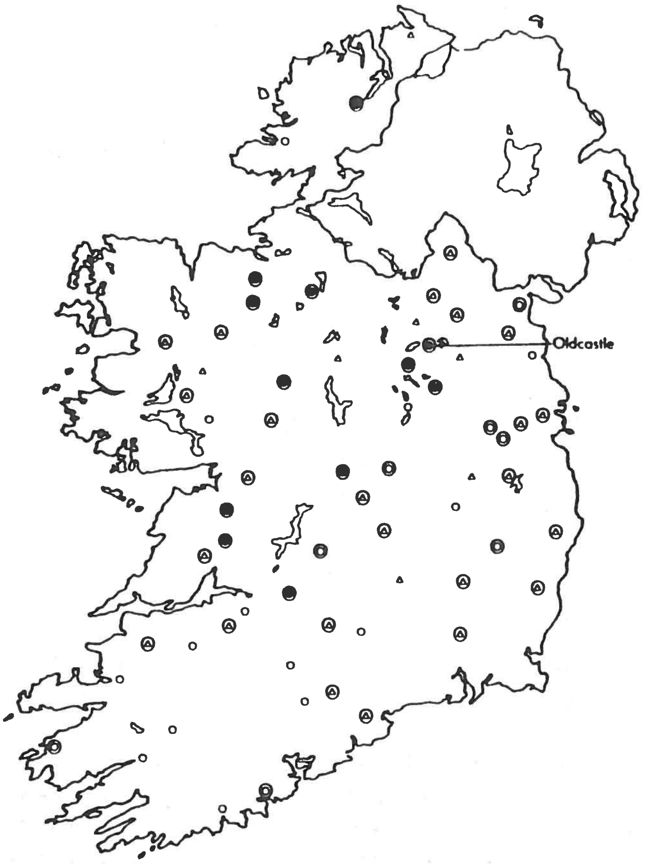


FIG. 1. REDWATER CASES TREATED BY SELECTED VETERINARY PRACTICES IN THE IRISH REPUBLIC.

o - < 100 CASES PER YEAR
△ - 100-300 " " "
● - >300 " " "
O - ↑ PREVALENCE OF 'ACUTE' CASES

Many veterinary surgeons suggested more than one reason for this trend, the most prominent being that an increase in parasite virulence and/or host susceptibility had occurred (Table 2). As expected the view that late calls were partly responsible was almost as prominent. The third factor, drug resistance, was implicated by a small,but nevertheless substantial, number of veterinarians.

Table 2. Ascribed causes of increasing prevalence of cases of babesiosis by veterinary surgeons.

Late call	67.0
Increased parasite virulence and/or host susceptibility	71.0
Drug resistance	42.0
Other	14.0

The most commonly used babesicide was Imizol* followed by quinuronium sulphate. This latter drug was implicated in resistance more often than the other drugs which is a reflection of the fact that it has been available for many years. In contrast Imizol has been introduced relatively recently. Diampron+ was probably the second most widely used drug before the introduction of Imizol and a considerable number of practices have implicated it in drug resistance. Berenil, although available for many years, has always had a small share of the market and resistance problems with this drug are apparently not common (Table 3).

Table 3. Veterinary practice use of babesicidal drugs and suspected resistance status.

Drug	Usage %	Resistance suspected %
Imizol	79.0	1.0
Quinuronium sulphate	53.0	19.0
Diampron	48.0	15.0
Berenil	30.0	6.0

A number of additional questions were asked of a total of 40 selected practices in a supplementary questionnaire and 26 of these were returned.

It was established that most practices (65%) were of the opinion that the increase in revisits applied to cases requiring emergency treatment for acute anaemia rather than toxicity, jaundice and other complications. Nervous symptoms were encountered by most of the vets. (74%) but all these considered them to be rare and to consist essentially of behavioural changes due to brain anoxia. The vast majority of vets. (91%) encountered apparent failures of the prophylactic use of Imizol and all these indicated that cases of redwater occurring after treatment with this drug were invariably mild.

In addition to providing information on the prevalence of acute cases of babesiosis the survey also showed that a large number of babesiosis cases occur each year in this country and that the disease is very widespread. Every county is affected with most cases occurring in areas around and to the west of

* Wellcome Foundation Ltd. + May & Baker Ltd.

the Shannon system (Fig. 1). The lowest prevalence occurred in the south-west of the country.

Farm survey

The percentage return (29.5%) of the 274 questionnaires sent out was low and probably reflected the complexity of the questionnaire.

A substantial number of farmers were of the opinion that "hard cured" cases had become more prevalent in the last 10 years but "no change" was recorded by most of them and very few recorded reduced prevalence. This suggests that the problem may be restricted to particular farms (Table 4).

Table 4. Farmer's opinion of change in prevalence of "difficult" cases of babesiosis in the Oldcastle area over last decade (n = 81).

Change	%
Increased	35.0
Decreased	6.0
No change	59.0

Changes in farming practices involving land improvement, land rental, new breeds, age of cattle and stocking rate were very similar for the 58 na-c farms (48.2%) and for the 23 that experienced acute cases in 1982 (48.8%), however, it was found that fewer na-c farms had made land improvements compared with a-c farms (Table 5). This ties in with the finding that when land type was assessed and graded for redwater risk (based on tick habitat and stock susceptibility) it was found that there was greater association between a-c farms and the lower risk grades than for the na-c farms (Table 6).

Table 5. Changes in type of land used over last decade in relation to babesiosis.

Change	1982 non-acute case farms % (n = 58)	1982 acute case farms % (n = 23)
Improved (reclaimed, re-seeded, drained etc.)	7.0	26.0
Rented	14.0	9.0
No change	79.0	65.0

Table 6. Redwater risk rating of land (low = 1, very high = 5)

Rating	1982 non-acute case farms %	1982 acute case farms %
1	7.0	5.0
2	10.0	23.0
3	31.0	55.0
4	38.0	13.0
5	14.0	4.0

Stocking rates had increased on about a third of farms in both categories with apparently no decrease in stocking rates on any farm. Most stock in both categories were home reared.

Neither mineral deficiency problems nor the association of breed with acute cases were recorded often, but it was found that these two factors were much more prominent on a-c farms.

Very few farmers (9%) had used growth promoters in affected animals so this factor is very unlikely to be involved in the increasing prevalence of acute cases.

Most farmers claimed to request veterinary assistance immediately a case was detected (Table 7). The proportion of a-c farms that initiated treatment themselves was lower than for na-c farms.

Table 7. Source of initial treatment of babesiosis cases.

	1982 non-acute case farms	1982 acute case farms
Farmer	45.0	22.0
Vet.	55.0	78.0

Only 32% of farmers identified the drug they used to treat their cattle and of the 4 compounds currently available quinuronium sulphate preparations were used by the vast majority. None of the farmers used Berenil* (Table 8).

* Hoechst Ltd.

Table 8. Babesicidal drugs used by farmers.

Drug	%
Quinuronium sulphate	81.0
Imizol	11.0
Diampron	8.0
Berenil	0.0

DISCUSSION

This study has provided evidence to suggest that the phenomenon of increasing prevalence of acute or unresponsive cases of babesiosis is both widespread and is due to a genuine change in the epidemiology of the disease.

It was anticipated that the most likely explanation for the trend would be that farmers were not requesting veterinary assistance until they had attempted treatment themselves and that cases were then in need of additional emergency treatment. Many vets. concurred with this view but this was not the predominant explanation they provided. Furthermore, a minority of farmers in the Oldcastle area attempted treatment themselves before calling the vet., so that this explanation appears to be inadequate.

The suggestion that cattle have become more susceptible to the disease was made by most vets. and received support from circumstantial evidence. Such increased susceptibility is likely to arise if the overall transmission rate falls so that fewer animals are infected as relatively resistant calves. This would mean that increasing numbers of animals would become infected for the first time in older age groups, when they are more susceptible to clinical disease.

It is generally accepted that the type of habitat suitable for the vector tick of babesiosis, Ixodes ricinus, has been much reduced in the last decade, particularly on home farms. It is probably relevant that relatively more a-c farms in this area were graded in the lower redwater risk categories compared with the na-c farms sampled and these farms had also made more land improvements over the past decade. Since home reared animals predominate in this area it is probable that tick populations are no longer large enough to infect cattle as calves in the same numbers as 10 years ago. The continued practice in the area of renting extra and badly maintained grazing for older animals would exacerbate the situation.

No information was obtained to suggest that cattle movement patterns, which are extensive (O'Sullivan, 1975) had changed markedly either in the Oldcastle area or nationally, though some vets. mentioned this factor as being specifically involved in the increasing prevalence of acute cases.

Although the continued presence of drug residues may play a part it is probable that the main reason for the mildness of cases occurring after Imizol prophylaxis is due to the fact that cattle have acquired low level infections while protected by drug prophylaxis. This was sufficient to moderate clinical responses to subsequent infections and models the situation obtaining in the past when young resistant animals received sufficient infection to withstand completely or partially clinical reactions on infection as older animals.

Drug resistance was not expected to be as prominent a factor in the veterinary survey as it proved to be. Some vets. contacted personally were most emphatic that resistance to at least some of the drugs occurs, but some maintain that all drugs were equally ineffective in the acute cases under consideration. It is not impossible that drug resistance is still involved in the latter case in view of the analogous situation in drug resistance to human malaria where resistance to new compounds developed very much faster than it did to some of the older ones (Peters, 1983). This subject is receiving further attention.

It has been suggested that Babesia bovis, which causes cerebral babesiosis has been introduced in continental cattle over the past few years and may contribute to the increased prevalence of acute cases, but although most vets. encountered nervous symptoms on occasion, they did not appear to accord with those for B. bovis (Zwart & Brocklesby, 1977). A total of 19 isolates from acute cases were examined and no typical B. bovis forms were detected.

Although Haigh & Hagan (1974) suggested that unresponsive cases of babesiosis were associated with farms with copper and/or cobalt deficiency problems and copper deficiency is likely to arise with land improvements the surveys did not indicate such an involvement. Furthermore, a small survey consisting of blood copper analysis of samples from acute cases, a-c farms and randomly selected farms failed to provide any evidence in support of this hypothesis. The data from all three sources were, however, relatively crude and further studies of a more experimental nature are required.

The veterinary surgeon survey together with data from previous studies (Gray et al., 1983) has provided the basis for a rough estimate of the cost of babesiosis in the Republic of Ireland (Table 9). From the data obtained a total of nearly 104,000 cases per year may occur giving an annual percentage incidence of 1.5. This agrees very closely with the results of a farm survey* involving 500 farms across the country with a minimum of 60 head of cattle in which the redwater incidence was found to be 1.7%. From these figures the cost of mortality and treatment is estimated to be IR£. 7-8 million p.a. If losses in productivity could be quantified the overall figure might well be twice this figure.

Table 9. Estimation of economic importance of bovine babesiosis in the Republic of Ireland

Average annual number of cases per practice surveyed.		148
Total number of practices		350
Total number of cases seen by veterinary surgeons per year		51,800
Total number of cases occurring per year (X2 above)		103,600
Number of deaths per year at mortality rate of 10%.		10,360
Annual cost of mortality	IR£.	6,216,000
Annual cost of treatment	IR£.	1,165,500
Mortality and treatment cost per year	IR£.	7,381,500

* Carried out by Thomas Healy and Associates.

It is evident that current treatment and control measures are inadequate. The most acceptable control measure for this disease would be vaccination. With recent developments in *in vitro* culture of *Babesia* the development of the gerbil as a laboratory host, hybridoma technology and genetic engineering this objective is now attainable given adequate commitment.

SUMMARY

1. Surveys of farmers in a local area and of veterinary practices throughout the country have indicated that the prevalence of severe cases of babesiosis has increased considerably over the last 10 to 15 years.

2. Although there is a tendency for farmers to call veterinary surgeons to cases at a later stage in the progress of the disease than in previous years, this is not an adequate explanation for the phenomenon. It is suggested that the primary reason for the trend is the breakdown of enzootic stability, resulting from the destruction of tick habitat which has caused a decline in transmission rate and in the immune status of the cattle population.

3. Preliminary investigations on the role of mineral deficiency in the phenomenon suggests that copper deficiency is probably not involved, although more work on this subject is required. Resistance of parasite strains to curative drugs was implicated by many veterinary surgeons and further studies on this are in progress.

4. The data from these surveys together with those from previous studies suggest that the economic loss caused by bovine babesiosis in the Irish Republic is at least IR£. 10 million per year.

ACKNOWLEDGEMENTS

We are grateful to Dr. J. Mannion and Mr. J. Phelan for advice on the surveys and to Dr. T. Murphy and Dr. D. Poole for assistance with the blood sampling and analysis.

REFERENCES

Gray, J.S., Fitzgerald, E. and Strickland, K.L. (1983). Prevalence of clinical babesiosis in an area in north Co. Meath, Ireland. Vet. Rec. 113 537-539.

Haigh, A.J. and Hagan, D.H. (1974). Evaluation of imidocarb dihydrochloride against redwater disease in Eire. Vet.Rec. 94 56-59.

O'Sullivan, M. (1975). The spatial structure of the Irish cattle economy. Agricultural Economics Society of Ireland, Feb. 1975. (Private circulation).

Peters, W. (1983). Chemotherapy of malaria. 2nd International conference on malaria and babesiosis Sept. 1983, Annecy, France. (Private circulation).

Zwart, D. and Brocklesby, D.W. (1979). Babesiosis: Non-specific resistance, immunological factors and pathogenesis. Adv. in Parasit. 17 49-113.

EPIDEMIOLOGICAL CHARACTERIZATION OF AN ACUTE EQUINE DIARRHOEA SYNDROME: THE CASE-CONTROL APPROACH

B. D. PERRY*, J. E. PALMER**, J. B. BIRCH***, R. A. MAGNUSSON*, D. MORRIS*** AND H. F. TROUTT*

During the last five years, a disease syndrome characterized by fever, anorexia, leucopaenia, acute diarrhoea and high mortality has been observed with apparent increasing incidence in horses of an area adjacent to the Potomac river in Montgomery County, Maryland, and in Fairfax and Loudoun Counties, Virginia. The number of clinically recognised and reported cases of this acute equine diarrhoea syndrome (AEDS, or Potomac Fever) reached 116 in the region during 1983 (Knowles et al, 1983). More than one third of these cases proved fatal or were destroyed. Although a similar syndrome has been reported from other parts of the United States, the dramatic increase in incidence has led to speculation that it is a new disease entity.

The disease appears to be seasonal, with the highest incidence between the months of June and September. No cases are reported during the winter months. Despite rigorous sampling procedures of clinically affected horses, and numerous post mortem examinations, no aetiological agent has been identified to date.

Little information is available on the horse population of the region, estimated to be about 6,000 in Montgomery County, Maryland, alone. With the apparent low incidence of the disease, it was decided to perform a case-control study to further characterize the epidemiology of the syndrome during the summer of 1983. This techique allows the estimation of relative risk associated with variables studied, by the calculation of the odds ratio (MacMahon and Pugh, 1970). This paper presents a preliminary analysis of the results.

MATERIALS AND METHODS

The case-control study was carried out in Montgomery County, Maryland and cases were identified by five veterinary practices. On the diagnosis of Potomac Fever, the owner of each affected horse was requested to answer questions on two questionnaires. The first related to the horse, and the second related to the premises at which it was kept. Questions covered management procedures at pasture and in the stable, movement of horses, contact with the disease, feeding practices, medical history and medication received. Both questionnaires totalled 135 questions. The interrogators were veterinary students from the two veterinary schools participating in the study.

---

* Virginia Maryland Regional College of Veterinary Medicine, VPI&SU, Blacksburg, Virginia 24061, USA.
** New Bolton Center, University of Pennsylvania School of Veterinary Medicine, 382 W. Street Road, Kennett Square, Pennsylvania 19348, USA.
*** Department of Statistics, VPI&SU, Blacksburg, Virginia 24061, USA.

Affected premises were then matched with unaffected premises, using the following criteria:

a) The same veterinary practice
b) Approximately the same number of horses
c) The same type of premises (e.g. boarding stables, breeding farm.)
d) The same geographic region of the county.

On each of the unaffected premises, 5 unaffected horses, matched with the affected horses for age and sex were then identified. In addition, 5 unaffected horses were identified on affected premises using the same matching criteria of age and sex.

Horse questionnaires were then completed for all control horses, and farm questionnaires for all control premises. The study thus comprised three groups of horses:

Affected on affected premises (AA)
Unaffected on affected premises (UA)
Unaffected on unaffected premises (UC)

The numbers in each group for which completed questionnaires were obtained are shown in Table 1.

Table 1. Study design: summary of completed questionnaires.

HORSES

Cases	Controls	
(AA)	Affected farms (UA)	Unaffected farms (UC)
68	84	108

PREMISES

Affected (A)	Unaffected (C)
21	20

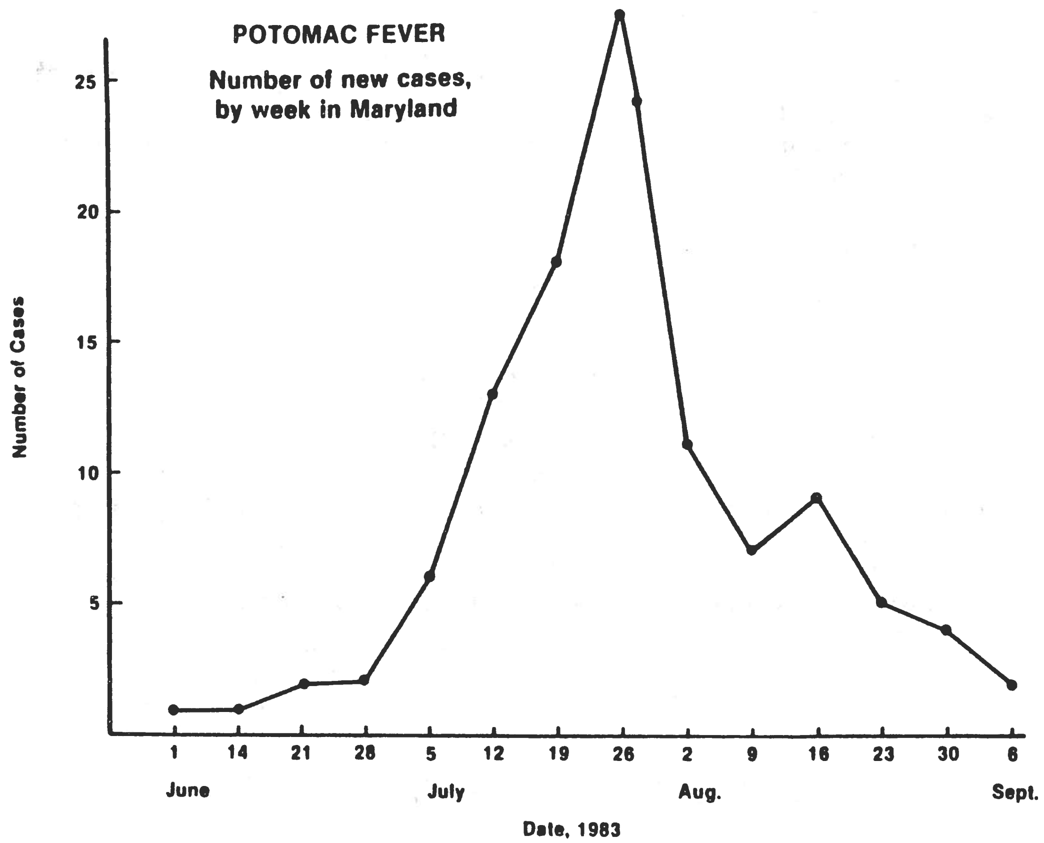
Serum and faecal samples were also taken from affected and control horses. Faecal samples were subjected to routine bacteriological analysis, and in addition, analysis for Clostridium difficile and C. perfringens Type A enterotoxins. Sera were retained at -40°C for future reference. Feed samples (grain and hay) were taken from affected and unaffected premises and analysed for gross abnormalities.

Data from the two questionnaires were computer processed. Each variable was analysed by both AA/UA and AA/UC comparisons using the Statistical Analysis System (SAS, Carey, North Carolina), and odds ratios were computed (Fleiss, 1981). Discriminant analysis was subsequently performed on a subset of 12 variables on the basis of a significant odds ratio and/or possible suitability as predictor variables using the procedures of STEPDISC, CANDISC and DISCRIM (SAS, 1982). This was run with both AA/UA and AA/UC comparisons.

RESULTS

The number of cases of Potomac Fever seen by week in 1983 is illustrated in Figure 1.

Fig. 1:



Age, sex and horse-use distributions were indistinguishable between the three groups AA, UA and UC, indicating satisfactory matching of horses for these criteria. When the distribution of these variables in the AA group was compared with that of all horses of the 41 premises studied, the variable of sex was directly comparable. Those of age and horse use indicated a greater proportion of horses of the age 7-10 years and of pleasure horses in the affected group than the horse population of all farms studied.

Results confirmed a lack of apparent association with horse density, both in the barn and at pasture, and little association with contact with the disease. Furthermore there was no indication of risk associated with common sources such as water and feed. The sporadic nature of the disease was also apparent. Seventy-nine per cent of affected horses had no other Potomac Fever horses on the pasture, and 67 per cent of affected horses were the only case in the barn. Fifty seven per cent of affected horses were thought not to have had contact with other Potomac Fever cases, but 90 per cent of unaffected horses on affected premises had been in contact with the disease. Nine per cent of affected horses had been affected in previous years.

Table 2 illustrates the results of odds ratio analysis of a limited selection of variables.

Table 2. Results of odds ratio analysis of selected variables.

Variable	Odds ratio.	
Pasture:	UA comparison.	UC comparison.
Number of other horses on same pasture	0.9	1.1 (p=0.6)
Size of currently used pasture	1.4	0.7 (p=0.05)
Presence of abundant forage on pasture	1.4	1.8±0.65 (p=0.003)
Use of fertilizer on pasture	0.8	0.6
Horses in adjacent pasture with PF in previous years	1.0	N/A
Barn		
Number of other horses using barn	0.6	1.1 (p=0.1)
Number of horses in barn previously affected (before 1983) with Potomac Fever.	3.1±1.2	N/A (p=0.0001)
Communal water administration	0.7	1.0
Use of sawdust bedding	1.5	2.9±1.1 (p=0.01)
General		
Place of birth elsewhere than farm where currently stabled	0.65	0.86 (p=0.8)
Presence of other livestock	1.8±0.7	3.1±1.3 (p=0.006)

N/A = Not applicable

Odds ratios could not be computed for all variables, due to the small numbers in some of the variable categories. Nevertheless, in many such instances marked similarities between the horse categories were seen. These included the variables of the material used for stall construction, the source of water in the barn and the pasture, the physical description of pastures currently used, the date when horses were turned out to pasture, the average number of hours per day at pasture and the mode of transport used for the introduction or movement of horses.

The discriminant analysis on the subset of 12 variables gave a canonical R^2 value of 0.24 for the full model. A 5-variable model was then selected, giving a canonical R^2 value of 0.21.

Microbiological assay of faecal samples did not reveal any significant isolations. Clostridial toxin analyses identified *C. perfingens* Type A enterotoxin in a small proportion of both case and control horses (Ehrich et. al. submitted).

DISCUSSION

Case-control studies have not been widely used as field investigation techniques in veterinary medicine, despite their extensive use in human medicine, although their frequency has certainly increased in recent years. The commonest setting has been for the retrospective analysis of hospital clinical data (e.g. Willeberg, 1975) and of slaughterhouse data (Willeberg et. al., 1978). Recently the use has expanded to identify relationships between diseases (Dohoo and Martin, 1983) and in the study of complex multifactorial diseses (Pritchard et. al., 1983).

In this study, the technique was chosen due to the low attack rate in the resident horse population (estimated at 19 per 1,000), the lack of available data on the characteristics of that population, and the unknown aetiology of the disease. It had the advantage over the more conventional studies using hospital or slaughterhouse data in that the control subjects were selected from the horse population at large, and not from a limited group of hospital admissions.

The decision to select two control groups (UA and UC) was made for two reasons. Firstly, in the absence of a definitive diagnostic test, it was not known what a true control was. Secondly, the selection of unaffected premises ruled out the calculation of the odds ratio by comparing with UC horses for certain parameters relating to the presence or previous presence of the disease. In these instances, AA/UA comparisons alone were made.

The problem of the identification of controls was of course extended to the identification of cases. It was decided to use the clinical classification of the five practices, based on the presence of fever, anorexia, leucopaenia, borborygmal sounds and diarrhoea, and supplemented by the failure to isolate Salmonella sp. Nevertheless, detailed clinical and pathological records were kept on each case, in order that subsets of the affected population could be identified and compared with controls at a future date if appropriate.

Another disadvantage of the technique was the use of a questionnaire format, which inevitably limited the depth of information obtained. The length of the questionnaire extended the analysis period over several months. However, these disadvantages are outweighed by the ability of the technique to characterize the epidemiology and identify potential risk factors within the period of one year.

The results clearly indicate a lack of association with most of the variables so far analyzed, at least at the depth permitted by the questionnaire. Significant positive risk associations were nevertheless found between the presence of the disease and its previous presence in the barn, and between the disease and the presence of other livestock on the pasture. A comparison of affected and unaffected farms showed that there was a greater proportion of dogs and cattle on affected premises than unaffected premises. The odds ratio of 2.9 associated with the use of sawdust bedding is difficult to explain. The identification of a greater proprotion of 7-10 year old horses in the affected population than in the total population of all farms studied, although not a valid analysis procedure of a case control study, deserves further investigation due to the representative nature of the control animals.

The discriminant analysis was performed to eliminate the effect of confounding variables. However, using variables with a significant odds ratio and others with potential as predictor variables, poor discrimination between affected and unaffected horses was obtained, unless the number of variables was reduced to five, and the comparison run only between AA and UC horses. In this instance, however, the sample size was reduced to 26, and all control horses represented came from 3 farms. The analysis is continuing.

In summary, the results indicate that the disease is not contagious, and if infectious, it is probably of a low infectivity (or a low challenge rate if arthropod-borne), or there is a high level of population immunity. This latter point seems unlikely, with all ages of horses affected. Furthermore, epidemiological evidence suggests that oral transmission is unlikely in the field, and that a 'point source' infection related to ingestion is therefore unlikely.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of Alexandra Eaton and Marian Shaw with data entry.

REFERENCES

Dohoo, I. R. and Martin, S. W. (1983). A modified case-control approach to identifying relationships between diseases. Proceedings of the Third International Symposium on Veterinary Epidemiology and Economics. Veterinary Medicine Publishing Company, Edwardsville, Kansas, pp. 53-58.

Ehrich, M., Perry, B. D., Troutt, H. F., Dellers, R. N. and Magnusson, R. A. (submitted). Acute diarrhea in horses of the Potomac River Area: examination for clostridial toxins. Journal of the American Veterinary Medical Association.

Fleiss, J. L. (1981). Statistical methods for rates and proportions. John Wiley and Sons, New York. p. 61.

Knowles, R. C., Anderson, C. W., Shipley, W. D. Whitlock, R. H., Perry, B. D. and Davidson, J. D. (1983). Acute equine diarrhea syndrome: a preliminary report. Proceedings of the American Association of Equine Practitioners.

MacMahon, B. and Pugh, T. F. (1970). Epidemiology; Principles and Methods. Little, Brown and Company, Boston. pp. 241-282.

Pritchard, D. G., Ewards, S. Morzaria, S. P., Andrews, A. H., Peters, A. R. and Gilmour, N. J. L. (1983). Case-control studies in the evaluation of serological data from respiratory disease outbreaks in cattle. Proceedings of the Society for Veterinary Epidemiology and Preventive Medicine, Southampton, 12&13 April, pp.131-138.

Statistical Analysis System (1982). Users Handbook. SAS, Carey, North Carolina.

Willeberg, P. (1975). A case-control study of some fundamental determinants in the epidemiology of the feline urological syndrome. Nordisk Veterinar Medicin, 27, 1-14.

Willeberg, P., Gerbola, M. A., Madsen, A. Mandrup, M., Keller Nielsen, E., Rieman, H. P. and Aalund, O. (1978). A retrospective study of respiratory disease in a cohort of bacon pigs. Nordisk Veterinar Medicin, 30, 513-525.

OBSERVATIONS ON THE CAUSES OF MORTALITY IN TWO LAYER CHICKEN BREEDING FLOCKS DURING 48 WEEKS OF LAY

P. E. CURTIS,* CATHERINE PAYNE-JOHNSON** & G. A. OPOKU-PARE***

The mortality that occurs in laying chickens is recognised to vary considerably from flock to flock and in European laying trials (1977 - 1980) the range was from 2.8 - 10.2% (Jones 1981). Little appears to be published on the cause of mortality since autopsies are usually only requested if mortality is considered to be excessive. In Britain mortality surveys have covered broiler breeder flocks (Jones et al 1978) and cage laying flocks (Randall et al 1977) but British "layer" breeding flocks have not been recently surveyed. Greater interest has been shown in conditions which affect production because of their economic importance but welfarists are increasingly concerned at relationships between ethological problems and the general health of livestock (Report 1982).

MATERIALS AND METHODS

Two flocks of parent hybrid laying chickens were surveyed, the white parents (WP) having hatched on 22.7.82. and the brown parents (BP) on 20.7.82. Both flocks had been reared in the same house on site A until 28.10.82. when they were transferred to a deep litter house at site B, each flock again occupying one half of this house, which had been previously thoroughly disinfected. Site B house had a central slat covered dropping pit over which were placed the continuous feeders and the automatic drinkers. Negative pressure ventilation, with 8 side-wall exhaust fans, allowed air to enter via the roof. The house was insulated with glass fibre. An automatic egg collection system, with 960 individual nest boxes, was installed. The stocking density was approx. 0.133 m^2 per bird. The flock was managed by experienced personnel with occasional help from novices at holiday times. Visitors were restricted. Full records of flock performance were maintained.

Necropsy

During the 48 week laying period (140 to 476 days of age), all the dead birds from both flocks were examined. Carcases

*Sub-Department of Avian Medicine,
** Dept. of Veterinary Pathology, University of Liverpool
Veterinary Field Station, 'Leahurst', Neston, Wirral L64 7TE.
*** P.O.Box 1465, Accra.

were collected on Monday and Thursday and occasionally on other days for most of the period, but daily visits were arranged during July and August. Necropsy was performed in accordance with standard procedures (Fowler 1982) and findings recorded in a written form which was subsequently converted to a computer file on which could be recorded case number, owner, farm, shed, species, breed, age, sex, type of bird, date, group size, diagnosis (1st and 2nd), name of veterinarian, and whether the bird had died or been killed. A numerical code for the expected diagnoses had been prepared and was added to when new conditions were encountered. An Apple II (48K) computer was used with a Data-Plan* programme, the file being stored on mini-discs and printed with an Anadex 80 column printer. Conditions diagnosed were recorded as primary if they were judged to be the major cause of death or the most important conditions observed. Secondary conditions were recorded only when they were considered to be especially significant or noteworthy.

Laboratory tests

These were restricted to selected cases, of suitable freshness and significance. Bacteriological culture, histopathology, and light and electron microscopy were used. Aerobic bacteriological culture of selected lesions was undertaken using blood and Maconkey agar (Oxoid Cm55 and Cm 116). For haemophilus detection 0.01% B nicotinamide anadine dinucleotide was incorporated in the media. Significant colonies were further examined using conventional techniques (Cowan 1974). For mycoplasma, culture swabs from the oesophagus, trachea, and cloaca of selected arthritic birds were applied to Channock medium which was incubated for 3 weeks. Infectious laryngotracheitis diagnosis was based on clinical evidence, electron microscopy and histopathology. Examinations for chlamydia relied on the tissue culture technique (Johnson and others 1983) using swabs from birds with active conjunctivitis.

RESULTS

In all 248 birds were autopsied, 12 of which were culls. Two birds with severe dermatitis were removed for observation and treatment and eventually recovered. Seven carcases (2.4%) were too decomposed for diagnosis and for 4 (1.4%) no diagnosis was recorded. The primary diagnoses recorded for the other birds are shown in Tables 1, 2 and 3, with details of the less common conditions listed separately, as are the secondary conditions noted.

Mortality in the brown flock (165 birds 5.18%) was significantly higher than in the whites (119 birds 3.85%). (0.01>P>0.005). The major difference between the two flocks was in the dermatitis primary diagnosis in 30 browns against 15 whites

* Farmplan Computer Systems Ltd., Ross on Wye

Table 1. Primary diagnoses: brown flock

	HENS			COCKS			TOTAL		
	No.	%	% DEATHS	No.	%	% DEATHS	No.	%	% DEATHS
Dermatitis	28	0.97	18.3	2	0.68	16.6	30	0.94	18.18
Internal layer	17	0.59	11.11				17	0.53	10.30
Cannibalism	13	0.45	8.50				13	0.41	7.88
Visceral gout	9	0.31	5.88				9	0.28	5.45
Lung congestion/oedema	8	0.28	5.20	1	0.34	8.33	9	0.28	5.45
Broken egg in oviduct	4	0.14	2.61				4	0.12	2.42
Accidental injury	8	0.28	5.20				8	0.24	4.84
Peritonitis	5	0.17	3.27				5	0.16	3.03
Impacted oviduct (egg material)	5	0.17	3.27				5	0.16	3.03
Egg impacted in oviduct	6	0.21	3.92				6	0.19	3.64
Fracture of leg bone	2	0.07	1.31				2	0.06	1.21
Emaciation	2	0.07	1.31	1	0.34	8.33	3	0.09	1.82
Necrotic hepatitis	6	0.21	3.92				6	0.19	3.64
Decomposed	1	0.03	0.65				1	0.03	0.61
Infectious laryngo-tracheitis	4	0.14	2.61				4	0.12	2.42
Tenosynovitis	1	0.03	0.65	5	1.70	41.66	6	0.19	3.64
Nephritis	3	0.10	1.96				3	0.09	1.82
Rupture of liver	4	0.14	2.61				4	0.12	2.42
Tortion of bowel	2	0.07	1.31				2	0.06	1.21
Undiagnosed	3	0.10	1.96	1	0.34	8.33	4	0.12	2.42
Other conditions	22	0.76	14.38	2	0.68	16.66	24	0.75	14.54
Total	153	5.29		12	4.08		165	5.18	
ORIGINAL FLOCK (P.O.L.)	2891			294			3185		

Table 2. Primary diagnoses: white flock

	HENS			COCKS			TOTAL		
	No.	%	% DEATHS	No.	%	% DEATHS	No.	%	% DEATHS
Dermatitis	11	0.39	10.38	4	1.6	30.77	15	0.48	12.60
Internal layer	21	0.74	19.81				21	0.68	17.65
Cannibalism	12	0.42	11.32				12	0.39	10.08
Visceral gout	3	0.11	2.83				3	0.10	2.52
Lung congestion/oedema	2	0.07	1.89				2	0.06	1.68
Broken egg in oviduct	6	0.21	5.66				6	0.19	5.04
Accidental injury	2	0.07	1.89				2	0.06	1.68
Peritonitis	3	0.11	2.83	1	0.4	7.69	4	0.13	3.36
Impacted oviduct (egg material)	3	0.11	2.83				3	0.10	2.52
Egg impacted in oviduct	2	0.07	1.89				2	0.06	1.68
Fracture of leg bone	6	0.21	5.66				6	0.19	5.04
Emaciation	4	0.14	3.77	1	0.4	7.69	5	0.16	4.20
Necrotic hepatitis	1	0.03	0.94	1	0.4	7.69	2	0.06	1.68
Decomposed	5	0.18	4.72	1	0.4	7.69	6	0.19	5.04
Infectious laryngo-tracheitis	2	0.07	1.89				2	0.06	1.68
Tenosynovitis	-	-	-				-	-	-
Nephritis	2	0.07	1.89				2	0.06	1.68
Rupture of liver	-	-	-				-	-	-
Tortion of bowel	1	0.03	0.94	1	0.4	7.69	2	0.06	1.68
Undiagnosed	-	-	-				-	-	-
Other conditions	20	0.70	18.87	4	1.6	30.77	24	0.78	20.17
Total	106	3.73		13	5.2		119	3.85	
ORIGINAL FLOCK (P.O.L.)	2840			250			3090		

Table 3. Primary diagnoses: all birds

	HENS			COCKS			TOTAL		
	No.	%	% DEATHS	No.	%	% DEATHS	No.	%	% DEATHS
Dermatitis	39	0.68	15.06	6	1.10	24.00	45	0.72	15.84
Internal layer	38	0.66	14.67				38	0.61	13.38
Cannibalism	25	0.44	9.65				25	0.40	8.80
Visceral gout	12	0.21	4.63				12	0.19	4.22
Lung congestion/oedema	10	0.17	3.86	1	0.18	4.00	11	0.18	3.87
Broken egg in oviduct	10	0.17	3.86				10	0.16	3.52
Accidental injury	10	0.17	3.86				10	0.16	3.52
Peritonitis	8	0.14	3.09	1	0.18	4.00	9	0.14	3.17
Impacted oviduct (egg material)	8	0.14	3.09				8	0.13	2.82
Egg impacted in oviduct	8	0.14	3.09				8	0.13	2.82
Fracture of leg bone	8	0.14	3.09				8	0.13	2.82
Emaciation	6	0.10	2.31	2	0.37	8.00	8	0.13	2.82
Necrotic hepatitis	7	0.12	2.70	1	0.18	4.00	8	0.13	2.82
Decomposed	6	0.10	2.31	1	0.18	4.00	7	0.11	2.46
Infectious laryngo-tracheitis	6	0.10	2.31				6	0.10	2.11
Tenosynovitis	1	0.02	0.39	5	0.92	20.00	6	0.10	2.11
Nephritis	5	0.08	1.93				5	0.08	1.76
Rupture of liver	4	0.07	1.54				4	0.07	1.41
Tortion of bowel	3	0.06	1.16	1	0.18	4.00	4	0.07	1.41
Undiagnosed	3	0.06	1.16	1	0.18	4.00	4	0.07	1.41
Other conditions	42	0.73	16.22	6	1.10	24.00	48	0.76	16.90
Total	259	4.52		25	4.59		284	4.53	
ORIGINAL FLOCK (P.O.L.)	5731			544			6275		

Table 4. Layer Breeders : Monthly mortality in two flocks (544 cocks and 5731 hens).

	DEC 8-31	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV 1-10	TOTAL
COCKS	4	7	1	2	0	2	2	0	2	3	1	1	25 (4.59%)
HENS	6	37	14	8	17	13	18	21	30	29	52	14	259 (4.5%)
TOTAL	10	44	15	10	17	15	20	21	32	32	53	15	284 (4.53%)
% ORIGINAL FLOCK	0.16	0.70	0.24	0.16	0.27	0.24	0.32	0.33	0.51	0.51	0.84	0.24	
% CUMULATIVE	0.16	0.86	1.1	1.26	1.53	1.77	2.09	2.42	2.93	3.44	4.28	4.53	

Table 5. Layer Breeders : Monthly mortality - some primary diagnoses.

	DEC 8-31	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV 1-0	TOTAL
DERMATITIS	1	2	5	2	5	6	4	4	2	4	9	1	45 (0.72%)
INT. LAYER/ OVIDUCT OBSTRUCTION	1	2	0	1	4	1	1	4	8	14	24	4	64 (1%)

which approached significance (0.05). The heavier and more docile browns also lost more with tenosynovitis, lung congestion, accidental injury and ILT than the whites and clinically they were also more severely effected by ILT.

Dermatitis was usually seen as a unilateral area of moist gray necrotic skin on the side of the body under the wing. Score marks suggesting cockerel claw damage as an initiating factor were visible in early cases. Staphylococci were readily recovered from the lesions. In some cases a more chronic form of this dermatitis was seen affecting the back and hip area. Dermatitis was also the most common secondary condition recorded and was associated with the following primary conditions: reproductive disorders (19), leg fractures (5) and bruised head (1).

Two unusual conditions observed were chondrosarcoma extensively affecting the superficial areas of the neck and body of a 52 week old white hen and a distinctive granulomatous lesion of the liver and spleen in two white hens, both aged 43 weeks, the cause of which could not be determined.

Monthly figures are shown in Tables 4 and 5. Egg production (see Fig.1) and fertility were satisfactory commercially. Shell quality declined towards the end of lay and broken shells of half normal thickness were found in several birds.

Attempts to recover chlamydia from 2 birds with ILT proved negative, but Haemophilus parainfluenza was readily obtained from such cases in the early stages. No mycoplasmas were recovered from 4 arthritic birds. 11/15 peritoneal swabs from internal layers yielded pure E.coli - 4 were sterile. Necrotic hepatitis lesions were thought to be the result of earlier infection, possibly during rearing and yielded no significant organisms.

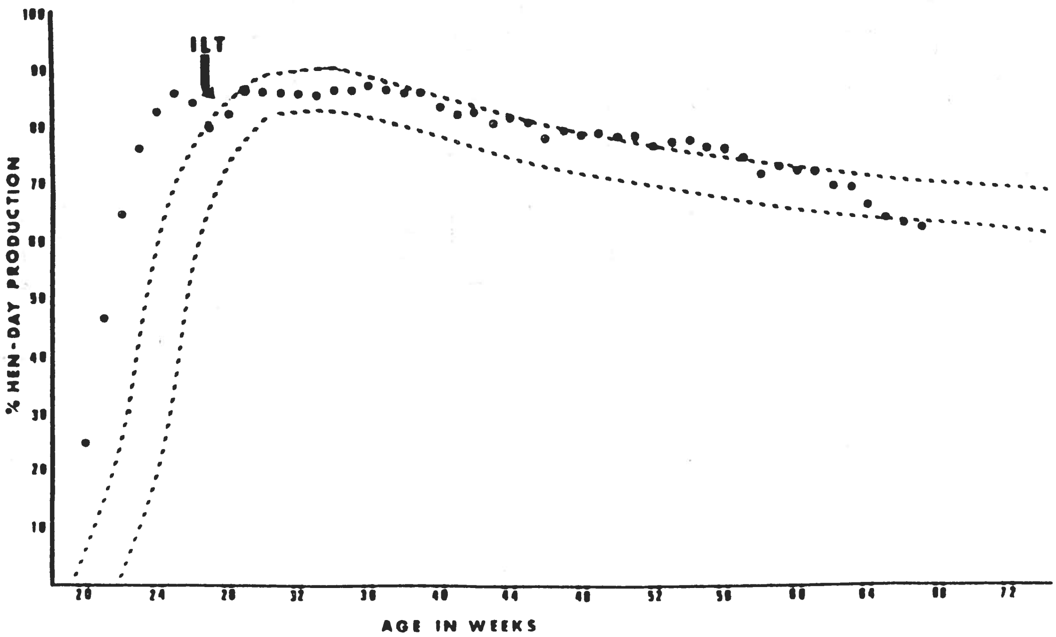


Fig. 1a. Egg production: white flock

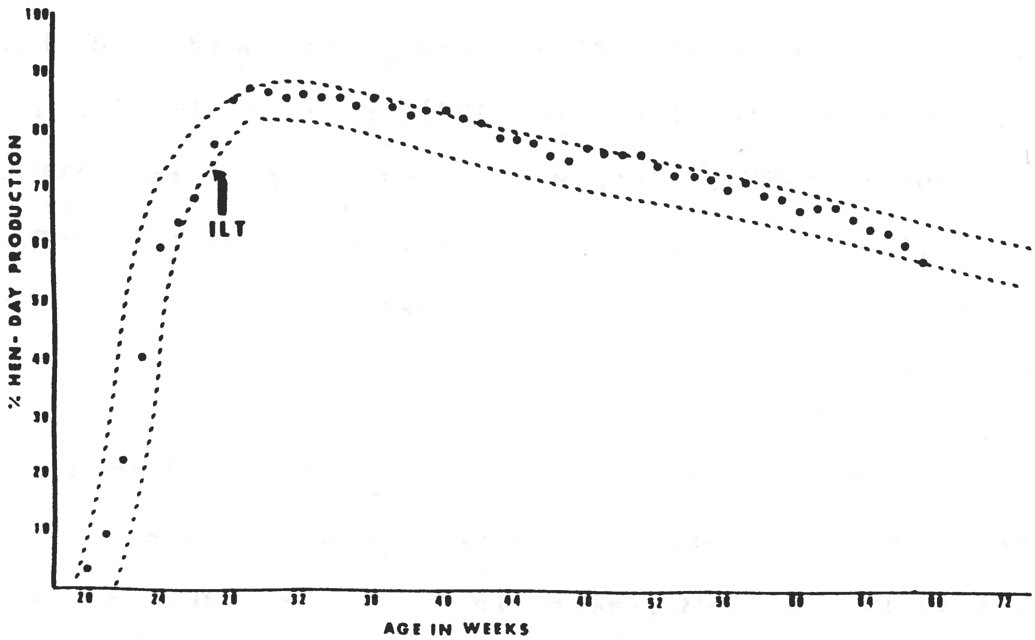


Fig. 1b. Egg production: brown flock

(1) Additional details of "other conditions" included in the primary diagnoses table are as follows :-

abdominal hernia (1WF), anaemia (2BF 1WF), articular gout (1BF), ascites (1BF 1BM), beak deformity (1BF), bruised head (1WF), bursitis, sternal (1WM), cloacal congestion (2BF), crop impaction (2WF), dehydration (1BF 1WM), enteritis (2WF), granuloma of liver/spleen (2WF), heart enlarged (2BF), heart failure (2BF), hepatitis (2BF 1WF), hip arthritis (1BM), intestinal obstruction (1WM), intestines perforated (1BF), ovary abnormal/haemorrhagic (2BF 1WF), oviduct (right) cystic (2WF), pericarditis (2BF), pneumoperitonitis (1BF), runt/dwarf (1WF), salpingitis (1WF), tumour conditions: chondrosarcoma (1WF), leiomyoma (1BF 2WF), ovarian tumours (2WF), leukosis (1WM 1BF).

(2) Secondary conditions recorded :-

In 79 birds a secondary condition was recorded in addition to the primary diagnosis and these were as follows :-

dermatitis (11BF 13WF 1WM), necrotic hepatitis (8BF), cannabalism (4BF 1WF), emaciation (3WF 1BF), leg fracture (2BF 1WF), Haemophilus parainfluenza (3BF), peritonitis (1BF 2WF), egg peritonitis (2BF), accidental injury (2BF), sternal bursitis (2BM), tenosynovitis (1BF 1WF), staphylococcal septicaemia (2BF), nephritis (2BF), and one case each of the following :- runt (WF), deformed beak (BF), fractured mandible (WF), distended crop (WF), staphylococcal arthritis (BM), bumble foot (BM), articular gout (WF), skin necrosis (WF), heat stress (BF), ureter obstruction (BF), oedema (WF), bruised head (WF), impacted oviduct (WF), broken egg in oviduct (BF), right oviduct distended (WF), tumour of ovarian ligament (WF).

DISCUSSION

The survey was undertaken to investigate the normal pattern of losses on the site against which past and future sporadic autopsies might be judged, and also to assess the value of the computer diagnosis recording system. One interesting finding was the diversity of conditions encountered, any one of which might have assumed, had conditions been different, much greater significance. This is very much a preventive medicine concept - to know what might happen and prevent it. For example the losses from ILT were surprisingly low indicating that the strain of virus involved was probably of low virulence (Curtis and Wallis 1983). The disease died out on the site without with use of vaccine, and is presumed to have been introduced to the flock originally by human movements.

The computer recording system was invaluable and the diagnostic coding was sufficiently flexible to allow for adjustment as new conditions were encountered. Secondary diagnoses were of value for recording selected conditions, such as H.parainfluenza infection or a fractured mandible which were considered particularly noteworthy, rather than for use in every case.

The importance of dermatitis had been suspected from sporadic autopsies on previous flocks and it is thought that the greater prevalence in brown birds is possibly influenced by the fact that the browns are heavier and more lethargic than the whites and that they also tend to crowd together more intensley, thus possibly creating an under-wing microclimate more favourable to infection of skin wounds. Stocking density having regard to weight may also be a factor. Dermatitis was not a major finding in the mortality survey of caged layers by Randall and others (1977) nor in a survey of broiler breeders by Jones and others (1978) although in the latter survey 12% of hen mortality was associated with lesions of cellulitis, mostly on the head, but also on the lateral aspect of the pelvis and thighs.

In the present survey the term internal layer is used for all cases of internal laying including the so called egg peritonitis. This group of conditions together with oviduct obstructions is a major cause of hen mortality under all systems of management and the cause in these survey flocks is probably physiological malfunction, with an increased incidence towards the end of lay. Interestingly both flocks were almost equally affected despite their disparity in size and temperament.

Among the less common conditions encountered articular gout was found in one bird as a primary diagnosis with no evidence of visceral gout or visceral urate deposit (Siller 1981). The unusual conditions of chondrosarcoma and liver/spleen granulomas would probably not have been detected in the normal course of affairs since neither coincided with a significant mortality peak.

It was commendable that only one death could be attributed to heat stress for at the same period other flocks in the vicinity were known to have suffered heavier losses during the hot summer weather and 34°C was recorded in the survey house. This illustrates the importance of sound husbandry for the staff had carefully monitored ventilation. In this respect it is essential to keep stockmen informed of any autopsy findings especially when the loss is in any way related to husbandry, since in that way the staff are motivated to increase their observation of the livestock under their care, with a view to preventing disease or detecting early signs of it.

Acknowledgements

Mrs. C. Taylor for technical help, Mr. D. R. Jones for mortality information, Dr. R. C. Jones for electron microscopy, Mr. F.W.A. Johnson for chlamydia work, farm staff for co-operation, and Mr. Peter C. W. Williams for computer advice.

REFERENCES

Curtis, P. E. and Wallis, A. S. (1983). Infectious laryngotracheitis. Veterinary Record, 112, 486.

Cowan, S. T. (1974). In: Cowan and Steel's Manual for the identification of medical bacteria 2nd ed. Cambridge University Press, London.

Fowler, N. G. (1982). In: Poultry Diseases 2nd Ed. Ed. R. F. Gordon and F.T.W. Jordan. Ch.13. Bailliere Tindall: London.

Johnson, F.W.A., Clarkson, M.J., Spencer, W.N. (1983). Direct isolation of the agent of enzootic abortion of ewes. (Chlamydia psittaci) in cell cultures. Veterinary Record 113, 413-414.

Jones, D. R. (1981). 1977-1980 Report of random sample egg production tests in Europe. Agricultural Development and Advisory Service. M.A.F.F., Wolverhampton.

Jones, H.G.R., Randall, C.J., Mills, C.P.J. (1978). A survey of mortality in three adult broiler breeder flocks. Avian Pathology, 7, 619.

Randall, C.J., Blandford, T.B., Borland, E.D., Brooksbank, N.H., Hall, S.A., Hebert, C.N., Richards, S.R. (1977). A survey of mortality in 51 caged laying flocks. Avian Pathology, 6, 149-170.

Report of the Agricultural Committee of the House of Commons, Session 1980-81 (1982). Animal Welfare in poultry, pig, and veal calf production. H.M.S.O. London p.9.

DATA RECORDING AND ANALYSIS IN DAIRY HERDS

THE USE OF A COMPUTERISED HERD FERTILITY MONITOR

J M BOOTH* and M E WARREN**

Dairy farmers in the official UK milk recording schemes also record calving and service dates in order to determine lactation lengths and drying off dates for their cows. Within the National Milk Records (NMR) scheme operated by the Milk Marketing Board of England and Wales a service, called Checkmate, became available in 1982 to analyse these data.

FORMAT

A monthly report is sent to the farmer approximately two weeks after the recording date, at the same time as his normal NMR report. This consists of a herd summary (Figure 1) and a herd profile (Figure 2).

Figure 1 has three subheadings for the analysis of interval to first service, inter-service intervals and service success. The first two columns cover a twelve month period or the option of a service season, whilst the third and fourth cover the most recent 30 day period. Four important items are marked with asterisks; these are the average interval to first service, the percentage of cows holding to first service, the average number of services per cow holding, and the average interval to assumed conception. The latter is the figure given most emphasis and is the one upon which most analyses are based. Also included is a small number of target figures in parentheses. These targets are somewhat tighter than those set by Morrow (1981) and comparatively few herds attain them except in the service success categories. Their use in this form is being reconsidered.

Essential to the whole summary is the definition of "service success". As the system depends entirely upon recorded data, without any additional clinical input, conception is assumed when a period of at least 30 days has elapsed without a repeat service. Because recording, and the collection of data, is carried out monthly, this effectively means that a 30 to 60 day period has elapsed, ie no repeat service between 5 January and 4 February in the example herd in Figure 1. However, this inevitably gives unduly optimistic figures in the monthly figures in the right hand columns and so, following a small poll of veterinary surgeons with several clients in Checkmate, it has been decided to move this back one month, so the period will be 60 to 90 days from the previous insemination.

The herd profile (Figure 2) provides the data from which the summary is derived. This lists the last two calving dates, the number of days from calving if not yet served (eg cow 31), the dates of all services, the between service intervals, and the days from calving to assumed conception, which will refer to the previous lactation if a cow is not yet served (cow 31) or is not yet assumed to have held (cow 42).

*Milk Marketing Board Veterinary Laboratory, Lower Wick, Worcester WR2 4NS.
**Milk Marketing Board, Farm Management Services, Thames Ditton, Surrey KT7 OEL.

MR A FARMER
HOME FARM
NEW TOWN
OLDSHIRE

CHECKMATE

THE MMR HERD FERTILITY MONITORING SYSTEM

HERD SUMMARY

FOLLOWING RECORDING ON 5/ 3/84

NMR 11 11111/1 FMR&C 000X0000 MR A FARMER

NB. * = KEY FIGURES
[?] = REQUIREMENT FOR A 365 DAY CALVING INTERVAL
SERVICE DATES INCLUDED FOR CURRENT LACTATIONS ONLY

FIRST SERVICE

		SERVED IN PERIOD 06/03/83 TO 05/03/84			SERVED IN 30 DAYS TO05/03/84	
* AVERAGE INTERVAL TO FIRST SERVICE (DAYS) :		74		[60]	74	*
COWS FIRST SERVED AFTER :		NO.	%		NO.	
	1-45 DAYS	4	3		1	
	46-60 "	32	23		4	
	61-75 "	52	37		9	
	76-90 "	33	23		2	
	91+ "	21	15		3	
COWS NOT SERVED 60-180 DAYS AFTER CALVING		19				

INTER-SERVICE

COWS WITH SERVICE INTERVALS IN RANGE :		NO.	%	NO.
	1-17 DAYS	13	9	1
	18-24 "	58	42	10
	25-35 "	16	12	3
	36-48 "	29	21	5
	49-90 "	14	12	1
	91+ "	6	4	0

SERVICE SUCCESS

		04/02/83 TO 04/02/84			30 DAYS TO 04/02/84		
SERVICES AND COWS HOLDING :		NO. SERVED	% HELD		NO. SERVED	% HELD	
*	1ST	125	46	[60]	20	75	*
	2ND	66	35	[60]	19	42	
	3RD	33	58	[60]	6	50	
	4TH+	19	53	[60]	3	33	
* AVERAGE SERVICES PER COW HOLDING :		2.21		[1.65]	1.78		*

	NO.	
COWS CURRENTLY HOLDING	110	
COWS CURRENTLY IN HERD	220	
COWS CULLED/DIED IN SUMMARY PERIOD	45	20

* AVERAGE INTERVAL TO ASSUMED CONCEPTION 99 DAYS [+ 14 DAYS ON A 365 CI] *

Fig 1: Example herd summary

CHECKMATE

THE MMB HERD FERTILITY MONITORING SYSTEM

MR A FARMER
HOME FARM
NEW TOWN
OLDSHIRE

HERD PROFILE

FOLLOWING RECORDING ON 5/ 3/84

NMR 11 11111/1 FMR&C 000X0000 MR A FARMER

LINE NO.	CALVING DATES		DAYS FROM CALV	SERVICE DATES					INTERVALS					DAYS OPEN	LINE NO.
	PREVIOUS	CURRENT		1ST	2ND	3RD	4TH	5TH	C-1	1-2	2-3	3-4	4-5		
15	20/ 5/82	18/ 9/83		3/12/83					76					76	15
19	8/ 9/81	19/ 3/83		7/ 5/83	20/ 7/83				49	74				123	19
31	2/ 3/83	28/ 2/84	6											83	31
42	6/ 9/82	15/10/83		11/12/83	4/ 1/84	23/ 1/84	24/ 2/84		57	24	19	32		124	42
45	5/10/82	10/ 9/83		27/11/83	14/ 1/84	3/ 2/84			78	48	20			146	45
47	15/ 1/82	13/ 1/83		11/ 3/83	24/ 3/83	3/ 4/83	30/ 4/83	21/ 5/83	57	13	10	27	21		47
47				11/ 6/83	2/ 7/83				21	21				170	47
52	16/ 5/82	15/ 4/83		17/ 6/83	8/ 7/83				63	21				84	52
70	8/ 6/82	20/ 8/83		11/11/83					83					83	70
75	27/11/82	20/12/83	76											108	75
78	6/ 3/82	6/ 4/83		23/ 6/83					78					78	78
81	8/ 9/82	4/10/83		27/11/83	17/12/83	6/ 1/84	28/ 1/84		54	20	20	22		116	81

Fig 2: Example herd profile

RESULTS

a) Example herd

The herd shown in Figure 1 was used during the trial period, the first printout being produced in September 1981. At that time the average calving to assumed conception interval of the herd was 123 days. By the end of the first year this had been reduced by 17 days, and a further improvement of ten days was achieved in the second year, although it has recently edged up by three days to an interval of 99 days in February 1984.

The average calving to first service interval however was initially 69 days. This was subsequently reduced to 66 days, but has increased to 74 days over the last four months of November to February. This increase is likely to be the temporary effect of a management decision to tighten the calving period of the herd by stopping all services in July and August, in addition to September and October, and bringing forward the start of the breeding season by nine days to 1 November.

The proportion of cows holding to first service improved from 43% to 49% in the first year, but has now slipped back again to 46%. Do-it-yourself AI is now being tried in this herd in an attempt to improve this situation - it is not in an MMB AI area! The proportion of return to service intervals between 18 and 24 days has hardly varied from 41% originally to 42% now. The herd has regular advisory visits from the local veterinary surgeons who use the herd profile available on the farm and also receive copies of the monthly summary.

b) Checkmate herds

Analyses of the results of the herds in Checkmate have been carried out on several occasions, initially with the 20 trial herds and most recently extended to 255 herds participating in May 1983 (Warren, 1983). The overall average results have not changed significantly, as the total is being continually augmented by herds joining with comparatively poor results. It is hoped to carry out an analysis of longer-standing members once significant numbers have completed a year of membership.

In these analyses herds have been grouped according to their average interval from calving to assumed conception (C-C interval). The earliest analysis showed:

i) A highly significant relationship between the C-C interval and the average number of services per cow holding ($r = +0.72$, $p < 0.001$).

ii) A significant relationship between the C-C interval and the percentage of cows holding to first ($r = -0.56$, $p < 0.01$) and to second ($r = -0.50$, $p < 0.05$) service. As the percentage of cows holding to first service increased by 10%, so the C-C interval was reduced by 4.4 days.

iii) No relationship between the C-C interval and the average calving to first service interval ($r = +0.01$).

iv) No relationship between the C-C interval and the percentage of inter-service intervals of 18 to 24 days ($r = -0.15$).

v) No relationship between the C-C interval and herd size ($r = -0.15$).

vi) No significant relationship between the average calving to first service interval and the percentage of cows holding to first service (r = +0.35).

vii) A significant relationship between the percentage of short inter-service intervals of less than 18 days and the percentage of cows holding to first service (r = -0.48, $p<0.05$). As short inter-service intervals rose by 10%, so the proportion of cows holding to first service was reduced by 12%.

The average results for 255 Checkmate herds at May 1983 are given in Table 1, and compared to 25 herds with the shortest (best 10%) and longest (worst 10%) average calving to assumed conception intervals.

Table 1: Average results of 255 Checkmate herds (1983)

	All herds	Best 10%	Worst 10%
No. herds	255	25	25
Average calving to assumed conception interval (days)	103	82	129
Average herd size (cows)	137	106	122
Average calving to first service interval (days)	74	66	83
Inter-service interval of 18-24 days (%)	37	44	29
Cows holding to first service (%)	57	64	48
Cows holding to all services (%)	57	63	51
Average services per cow holding	1.75	1.59	1.95

Not unexpectedly, herds showed a wide range in performance, with a difference of almost seven weeks between the average calving to assumed conception interval of the best and worst group of herds. Even the overall average, at 103 days, was at least 18 days longer than that required for a 365 day calving interval. It was apparent that an appreciable proportion of this loss of time arose in the interval to first service. The worst group of herds would have required virtually a 100% conception rate in order to achieve the target 365 day calving interval; in fact they only attained half this.

Further losses were suffered by most herds by failure to observe returns in the 18 to 24 day interval after service. The figure of only 37% intervals falling into this range does seem very low, but it has been a consistent finding in the analyses. These herds are on average more than twice the national average size, which may make oestrus detection more difficult.

UPTAKE

Checkmate became available in September 1982 and after 18 months membership stood at 445 herds containing over 63,000 cows (D Batchelor, personal communication). Average herd size remained high at 141 cows, although individual herds varied from 17 upto 506 cows. As expected, membership rose more rapidly during the winter months (Figure 3). There is considerable regional variation with the southern and eastern regions having an appreciably higher proportion of recorded herds as members (Table 2). The correlation between the average herd size of a region and the proportion of milk recorded herds enrolled in Checkmate is highly significant ($r = +0.80$); as the herd size increases by ten cows so the regional membership of Checkmate increases by 1.5%.

Table 2: Regional membership of Checkmate (1983)

Region	Milk recorded (MR) herds	Checkmate herds No.	Checkmate herds % of MR herds
Eastern	775	73	9.4
South Eastern	769	50	6.5
Southern	788	43	5.5
East Midland	819	42	5.1
West Midland	1,259	44	3.5
Mid Western	1,753	46	2.6
North Western B	1,503	39	2.6
Northern	898	19	2.1
North Western A	1,898	35	1.8
Far Western	2,161	35	1.6
South Wales	1,107	18	1.6
North Wales	568	1	0.2
England & Wales	14,298	445	3.1

Dairy farmers joining Checkmate are encouraged to name their veterinary surgeon so that a copy of the monthly summary may be sent to him free of charge. Initially 67% of farmers named their veterinary surgeon, but it is disappointing to note that this has recently declined to 59%, and a small survey is under way to try to identify the reasons for this. Preliminary indications are that some farmers take the short-term view that more information to the veterinary surgeon may mean higher costs, and they prefer to control this themselves by only seeking professional advice when they decide it is required.

The original discussions with veterinary surgeons indicated that a copy of the monthly herd summary would best suit their purposes, with the herd profile remaining on the farm. Subsequently, however, there were official requests for copies of the profile to be sent to the veterinary surgeon on request, and approximately one-third of veterinary surgeons now receive this. There are now 20 veterinary practices with three or more clients using the service.

The present, April 1984, cost of Checkmate is £7.50 per month for the basic service, which includes two copies of the monthly summary and one of the herd profile for the farmer, and one copy of the summary for the veterinary

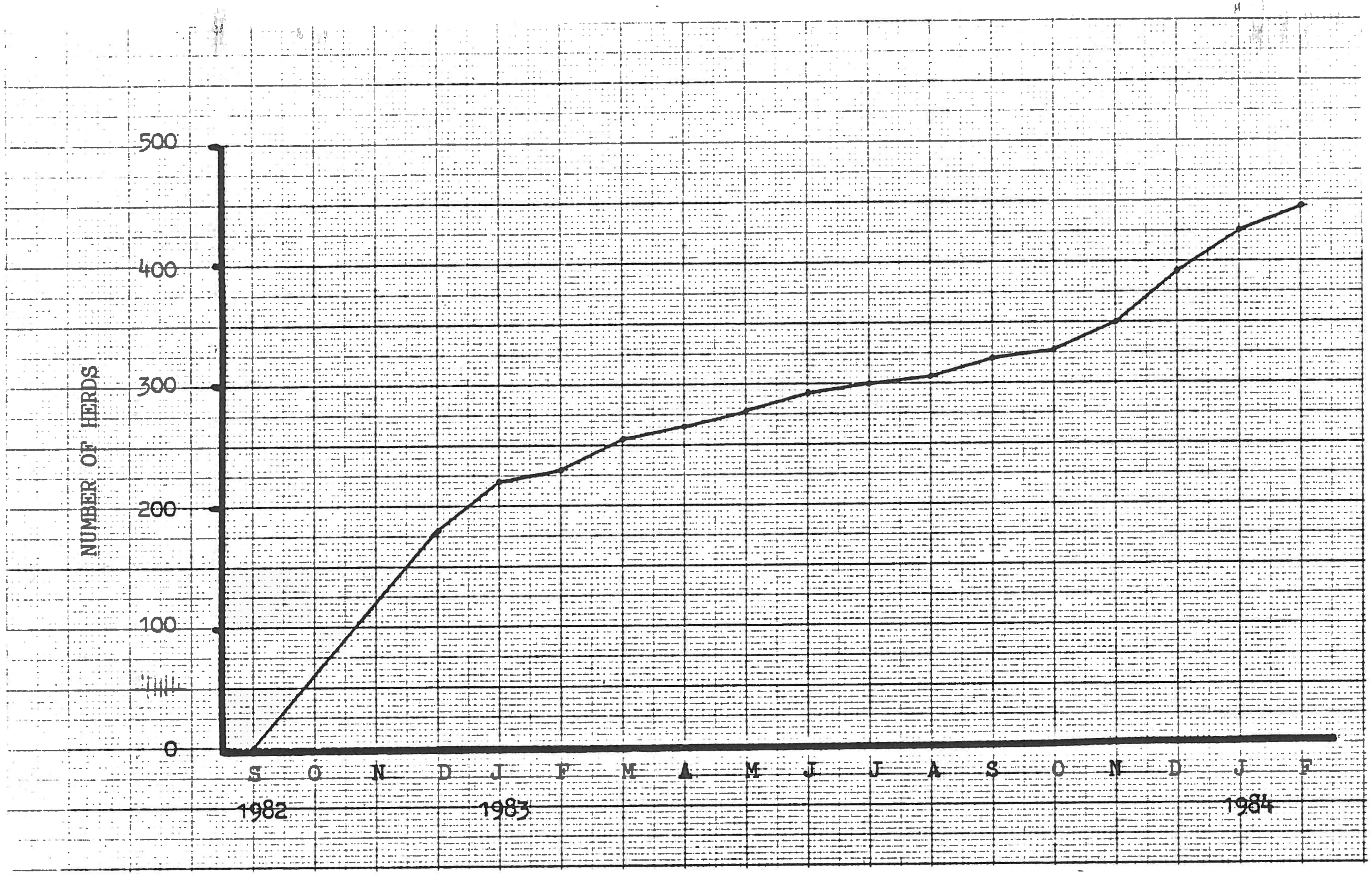


Fig 3: Checkmate membership to February 1984

surgeon and/or adviser as requested. An additional copy of the profile is available for £2 per month.

CONCLUSIONS

Checkmate makes use of data already available and so requires no extra recording, which is a major advantage to the busy farmer or herdsman. This fact also helps to keep the service cheap, less than £1 per cow for a 100 cow herd.

Inevitably there are weaknesses. The quality of the information coming out is only as good as the data going in, the summaries are historic, and there is no clinical or even laboratory confirmation of pregnancy.

Nevertheless, the monthly summaries can provide a simple means of monitoring the herd breeding performance. If the targets set by the farmer or his veterinary surgeon are not being attained, the summary provides a good indication of where to start an investigation, and the herd profile can supply easily accessible and detailed evidence.

REFERENCES

Morrow, D.A. (1981). Analysis of records for reproductive herd health programs. Irish Veterinary Journal 35, 27-31.

Warren, M.E. (1983). An analysis of survey data from herds taking part in a herd fertility monitoring service. Proceedings of the 34th Annual Meeting of the European Association of Animal Production, Madrid, Spain.

SIRO - A COMPUTER SYSTEM FOR DAIRY HERD RECORDING

E.A. GOODALL,* W.J. McCAUGHEY,** C.H. McMURRAY,** D. RICE**

The Veterinary Research Laboratory at Stormont acquired in 1977 a Hewlett-Packard desk-top microcomputer with a memory core of 24 K and floppy disk backing store. Research workers had been interested in the potential benefits to be derived from a system such as MELBREAD (Esslemont, 1974) and decided to set up a herd recording scheme based on the microcomputer. There was a considerable advantage in this system in that hardware and software were available to enable the microcomputer to emulate a terminal linked via private telephone line to a remote mainframe computer. There was therefore a "stand alone" capacity should the mainframe computer be unavailable and also a facility to switch data files to the mainframe computer where more sophisticated analyses could be performed and data retrieval and construction of reports more easily carried out if necessary.

The system was used on four medium to large commercial dairy farms in Northern Ireland and from each of which normally maintained records were collected and analysed over three seasons in the years 1979-1982. The primary aim of the scheme was to determine whether or not the monitoring of fertility problems and other disease problems on commercial dairy farms in Northern Ireland was feasible on a microcomputer and also to establish the usefulness of the collected data for research purposes. In the design of experiments to compare the effects of two treatments on fertility, large numbers of animals will be required to demonstrate practical differences. For example, if the variable under consideration is the calving rate to first service, then for a power of the statistical test of 0.9, and a calving rate in one group of 0.6, then to demonstrate a difference of 0.1 in the other group will require a sample size per group of 443 animals. Tables for the problem have been published by Walters (1979).

It is difficult, if not impossible, to obtain this number of animals for controlled experiments on one site. It was hoped that accurate fertility indices could be obtained for the four farms using a computerised record system. Secondary aims of the scheme were to determine if early detection of problems was possible and to assess which parameters might be most useful for this purpose. The scheme was entitled 'Stormont Investigative Recording Operation' (SIRO). The farms will be referred to as A, B, C and D.

*Biometrics Division, DANI and Department of Agricultural Biometrics, The Queen's University of Belfast.

**Veterinary Research Laboratory, Stormont, Belfast

SYSTEM

A farm entered the system initially by compilation of a stock log of all the animals on the farm together with all available recent fertility information (eg last calving date, last service date or last date seen in heat). A master index file was set up on the computer from this stock log and this served as a "look-up" table for validation purposes when information on a particular cow was received. The basic record for this index file consisted of three fields 1) ear tag number 2) freeze brand (-1 if not available) 3) index number.

On all farms, freeze brands were allocated only to milking cows or to pregnant heifers intended for milk production. The index number was automatically determined by order of entry onto the file so that, for example, if there had previously been 100 animals on the farm and a new heifer was purchased, this animal was allocated an index number of 101. The index file was regularly updated during the operation of the project. Each farm was allocated its own floppy disk and security copies of these disks were made regularly on the traditional "son-father-grandfather" data processing system. Once a farm had been entered on to the system, the raw data input for a file on the farm was a notebook kept by the farmer or dairy herd manager. In this notebook were recorded all events relevant to the fertility and health status of the herd. A basic entry might be, for example, "C146 served 21/10/81". This notebook was returned on a monthly basis to the laboratory and recorded for entry onto the computer. Each data record consisted of three fields:- 1) animal identifier 2) event code 3) date of event. At the point of input, the animal identifier could be either an ear tag number, or a freeze brand number, although usually the latter. This was checked by the computer against the index file and, if the identifier was found, the appropriate index number was allocated. A typical example of a computer record might be "96, 706, 3/4/82" where 96 is the index number for the cow and 706 the code for an AI service. A special system was devised for illnesses such as mastitis and lameness. If a cow had mastitis, the farmer was asked to indicate the form of mastitis using a simple diagram. An example is given in FIG 1.

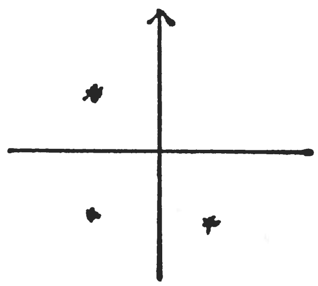


FIG 1 Example of mastitis coding for SIRO

This figure indicated that the cow had mastitis in one front quarter and the two back quarters. A different code was used for each type of mastitis.

The simple record described above formed the basis of an event data file for the farm. If an animal identifier could not be found at input, a check had to be made that the farmer had not made a mistake in his notebook. After entry and validation, a program was run to produce a summary report for the farmer. This program produced a number of tables under a number of different headings such as Calvings, Services, Mastitis, Lameness etc. When

TABLE 1

JUNE 1982 REPORT FOR FARM A

FREEZE BRAND	PREVIOUS CALVING DATE	LAST CALVING DATE	FIRST SERVICE	SECOND SERVICE	THIRD SERVICE	FOURTH SERVICE	SERVICE DUE	ESTIMATE CALVING DATE
188	02 MAR 81	27 FEB 82						
105	21 MAY 80	26 NOV 81						
204	18 DEC 80	27 FEB 82						
35	21 DEC 80	30 JAN 82						
126	29 MAR 81	14 FEB 82						
74	30 JAN 80	22 JAN 81	30 APR 81	25 MAY 81			15 JUN 81	04 MAR 82
210		16 FEB 81	10 MAY 81	01 JUN 81			22 JUN 81	11 MAR 82
19	25 JAN 80	05 MAR 81	25 APR 81	15 MAY 81	11 JUN 81		02 JUL 81	21 MAR 82
217		07 FEB 81	05 MAY 81	17 JUN 81			08 JUL 81	27 MAR 82
21	31 DEC 79	15 JAN 81	27 MAR 81	17 APR 81	01 JUL 81		22 JUL 81	10 APR 82
51	07 MAR 81	18 JAN 82	03 MAR 82				24 MAR 82	11 DEC 82
147	18 DEC 80	18 DEC 81	03 MAR 82				24 MAR 82	11 DEC 82
312			04 MAR 82				25 MAR 82	12 DEC 82
80	08 JAN 81	24 DEC 81	03 MAR 82	18 MAR 82	08 APR 82	30 APR 82	21 MAY 82	07 FEB 83
101	28 FEB 81	10 FEB 82	01 MAY 82				22 MAY 82	08 FEB 83
52	05 MAR 81	21 MAR 82	12 APR 82	01 MAY 82			22 MAY 82	08 FEB 83
102	26 DEC 80	02 JAN 82	09 MAR 82	17 APR 82	07 MAY 82		28 MAY 82	14 FEB 83
203	20 FEB 81	10 MAR 82	10 MAY 82				31 MAY 82	17 FEB 83
142	19 DEC 80	28 FEB 82	15 APR 82	10 MAY 82			31 MAY 82	17 FEB 83
75	13 FEB 81	05 FEB 82	31 MAR 82	15 MAY 82			05 JUN 82	22 FEB 83
106	22 DEC 80	23 FEB 82	20 MAY 82				10 JUN 82	27 FEB 83

the system had been in operation for a number of months and sufficient information on the fertility status of a farm obtained, a new program was utilised to produce a fertility report. A few lines extracted from one fertility report are reproduced in TABLE 1. All computer programs required for the system were developed relatively quickly because of the interactive nature of the system. The Hewlett-Packard itself could only be programmed in BASIC but since it could also emulate a terminal to a mainframe computer all the major languages and facilities of the latter were available. Ad hoc programs for various kinds of data retrieval were constantly required.

RESULTS

The most frequent problem in the early stages of the system was that of information in the notebook pertaining to an animal which had been introduced to the herd but of which the system was not aware. This proved to be a useful validation check and often wrong information could have been recorded for an animal. To counter this problem, a list of queries was circulated with each monthly report. There were frequent occasions when the need to check identity data delayed the calculation of accurate up-to-date statistics.

Two problems of a more complex nature arose with breeding information. The production of initial monthly fertility reports revealed some inconsistencies in the recording of calving data. It was obvious in many cases that there had been no record of calving dates. The second problem area was related to conception dates. Although all the farms on the project used the AI service, they also used natural service on cows which had gone out to grass and had not held to one or more earlier A.I. services. When cows calved, the date of service could be estimated. On examination of the data, these errors were found to be due to omissions from the notebook records and not wrong identity. The most reliable data received throughout the study related to calving dates. As a result, the only data considered either sufficiently complete or reliable to produce accurate indices were calving dates.

Culling rates over the three years are given in TABLE 2. The numbers culled for infertility, mastitis and other general reasons expressed as a percentage of numbers culled are given in TABLE 3.

TABLE 2

Culling rates (%)

Year	A	B	C	D
1	8.0	25.6	31.8	12.2
2	12.4	20.2	18.4	16.2
3	15.1	18.6	*	*

* missing data

TABLE 3

Summary of principal reasons for culling

Reason	A	B	C	D
Poor Production	1%	19%	14%	8%
Lameness	10%	3%	2%	3%
Mastitis	24%	17%	15%	13%
Fertility	52%	60%	36%	36%
Unknown	13%	1%	33%	40%

Average milk production data per cow are given in TABLE 4. A dairy herd survey carried out in Northern Ireland in 1978 estimated average production per cow per year to be 4200 (s.d. = 800) ℓ. The general management on the farms in the present study was considered above average for Northern Ireland. The increase in production on Farm A in Year 3 was coincident with a substantial increase in the quality of silage fed to cows in that year.

TABLE 4

Average Milk Yield (ℓ) per cow

Year	A	B	C	D
1	4430	5047	4018	5350
2	4424	4882	4354	4969
3	4936	5136	4974	5161

As a further measure of the validity of the data, mean gestation lengths were calculated for each herd for each season. The results are presented in TABLE 5.

TABLE 5

Mean gestation lengths in days (± standard deviation)

Year	A	B	C	D
1	282 ± 4	281 ± 4	282 ± 7	283 ± 5
2	282 ± 4	281 ± 5	280 ± 4	282 ± 5
3	283 ± 3	283 ± 4	280 ± 6	283 ± 5

Cows with calculated gestation lengths outside the normal limits of 270-290 days (Roberts, 1971) were not included in these statistics. If a cow had a calculated gestation length greater than 290 days and produced a normal calf, the last service was considered to have been omitted. This often occurred when the date of the estimated last service fell during the grazing season. Overall, 167 out of 1535 calvings (10.9%) occurred without a corresponding service date, ranging from 14.7% to 7.7% for the four farms. Calculated gestation lengths less than 270 days were less frequent and only gave cause for concern on Farm C in the 1980-81 season. Apart from the problem of registering abortions as normal calvings, the main reason for these abnormally short intervals was an extra service being recorded for a cow which had already conceived. There were other animals which were culled after the last recorded service. In the final year, confirmed calvings were not recorded for a number of animals on Farms C and D.

The analysis of the data showed considerable variation between farms. In the case of Farms A, B and C artificial insemination was used to breed cows during the housed period and a stock bull was introduced to the herd when first put out to grass. The data showed, for example, that on Farms A, B and D, the 5 and 6 estimated conception dates respectively which fell in March were within the final week of the month, at which time grazing had commenced. On these three farms, failure to record bull services was sufficient to account for 98% of the omissions. Farm C relied more heavily on natural service for breeding and the records showed that omissions occurred more frequently in this herd during the winter months. As expected, there was considerable variation between months in the proportion of calvings due to omitted conceptions ranging from 0% (November) to 36.0% (June).

The proportion of short gestations ranged from 1.1% (Farm A) to 5.4% (Farm C) but there was no pattern to the timing of these either in the duration of gestation or in the month at which premature delivery occurred.

Mean calving to first service periods are given in TABLE 6. These show that only on Farm A was the mean interval constant over years. Data from Farm B showed the longest interval and was possibly related to the management and feeding of this herd during the first season. Overall investigation of disease incidences on the farms revealed that many of the cows on Farm B in Year 1 had suffered from ketosis, possibly resulting in an anoestrus problem. This was followed by an attempt to advance the calving time of the herd in the succeeding two years. Farms C and D showed no consistent pattern.

TABLE 6

Mean calving to first service periods in days

Year	A	B	C	D
1	74	88	71	78
2	74	59	65	66
3	74	59	82	59

The computation of mean calving to conception intervals was difficult because of the problems discussed earlier. An attempt was made to compute more precise estimates by taking the calving dates for cows with gestation lengths greater than 290 days and subtracting 281 days from the calving date to estimate the true conception date. The estimated mean calving to conception intervals are given in TABLE 7. The estimated mean breeding delay periods are given in TABLE 8.

TABLE 7

Estimated mean calving to conception periods in days (± standard deviation). The range is in brackets

Year	A	B	C	D
1	89 ± 28 (153)	109 ± 54 (212)	90 ± 54 (184)	89 ± 26 (114)
2	88 ± 30 (139)	89 ± 44 (221)	81 ± 29 (118)	84 ± 31 (140)
3	83 ± 32 (152)	89 ± 39 (173)	95 ± 41 (179)	68 ± 24 (98)

TABLE 8

Estimated mean breeding delay period (± standard deviation)

Year	A	B	C	D
1	15 ± 23	22 ± 32	20 ± 37	11 ± 17
2	14 ± 25	31 ± 44	15 ± 25	17 ± 24
3	9 ± 17	31 ± 34	14 ± 25	16 ± 19

Calving rates to first service were calculated for each farm for each year and are given in TABLE 9. The arcsine root transformation was applied to these proportions and the table analysed as a randomised block experiment. Using the F-test, a significant difference was found between the means ($P<0.05$). The transformed means were 0.945, 0.728, 0.952, 0.850 with standard error 0.042. Using a t-test, the mean rate on Farm B was found to be significantly different from Farms A and C ($P<0.01$).

TABLE 9

Calving rates to first service

Year	A	B	C	D
1	0.60	0.56	0.69	0.65
2	0.66	0.35	0.63	0.54
3	0.71	0.42	0.67	0.50
Mean	0.66	0.44	0.66	0.56

A detailed study of inter-service intervals enabled an estimate of heat detection rates on the 4 farms to be made. For example, if a cow was served unsuccessfully at 72 days after calving and then conceived to a service at 114 days after calving with no intermediate service having been recorded, it was deduced that one heat had been missed. The estimated rates are given in TABLE 10. Apart from Farm B, there tended to be an improvement in heat detection rate over the three years. Farm C, in particular, seemed to benefit from computerisation of the records. The same analysis of variance as for TABLE 9 was performed and significant differences were found between the means ($P<0.05$). Using a t-test, the mean rate for Farm B was found to be significantly different from Farm A ($P<0.05$) and Farm D ($P<0.01$). The mean rate on Farm C was also significantly different from Farm D ($P<0.05$).

TABLE 10

Estimated heat detection rates

Year	A	B	C	D
1	0.75	0.62	0.58	0.79
2	0.64	0.60	0.69	0.76
3	0.83	0.59	0.70	0.88
overall	0.70	0.60	0.67	0.79

DISCUSSION

The four farms all had the same broad aims regarding general reproductive efficiency. In Northern Ireland, the usual desired aim is to achieve conception rates of 60% to 70% (55% to 65% calving rates).

The normally maintained records on these farms were shown to contain major inaccuracies and to be incomplete. Hence, only calving to calving could be calculated consistently and accurately. Calculation of other indices involved varying degrees of adjustment of the raw data which could have introduced unwanted errors. It must be concluded, therefore, that more attention to detail of recording will be required before totally reliable 'on-farm' data becomes available.

Only Farm B seems to have had a serious problem. A long calving to calving interval in Year 1 was followed by an attempt in the following year to serve a number of animals too soon after calving. This resulted in a greatly reduced calving rate to first service. On Farm A, there was a general aim that all cows should calve within the three month period, December to March. Very few cows calved outside this period. In 1980, for example, 1 cow calved in April, 3 in May and 2 in November. On Farm D, there was a general aim that cows should calve within the period November to February. In 1980, 3 calved in March, 4 in April, 2 in June and 4 in October. Farm C placed greater reliance on natural service using two bulls on the farm. There was a general aim that cows should calve in the period September to December. This was certainly not being achieved at the beginning of the study. A large percentage of animals were calving in the spring and early summer. However, in 1982, these figures were reduced to 7 cows calving in February, 1 in March and 1 in June. On Farm B, there seemed to be an aim that cows should calve in the period October to January but in 1981, for example, 23 cows calved in April. The varied calving pattern on this farm over the years may have stemmed from the initial problem on the farm in Year 1.

Since 1979, various other microcomputer-based herd recording schemes have been put into practice. MELBREAD has been superseded by DAISY (Veeru, 1980). Other major systems such as COSREEL (Russell and Rowlands, 1983) have been developed. There can now be little doubt as to the usefulness of these systems in the management of large dairy herds. However, the usefulness of the collected data for research purposes is debateable. There is also a problem in that data required for information management purposes may be stored and processed in a way entirely unsuitable for the purposes of statistical analysis. A problem is to match the fertility information with all the other management information available from a number of different sources. Data on milk yield is usually obtained from official milk recording schemes on which samples are taken once a month. This is useful to estimate total yield when the lactation is complete. Far more detailed data are required for research purposes. An estimate of average daily milk yield per week for each cow would be preferable. Various automatic systems and hand held recording devices are now available for this purpose. Such a system has been developed at the Agricultural Research Institute of Northern Ireland at Hillsborough where milk yields are recorded for each of the 180 cows twice daily. A hand held recording device is interfaced with a Digital PC 350 microcomputer. The latter can hold all relevant data for the dairy herd and operates as a stand-alone system. However, it can also emulate a terminal and is linked to the VAX 11/750 computer in the Department of Agricultural Biometrics of the Queen's University of Belfast where more sophisticated data analyses are performed. All archiving is also done on the VAX computer using magnetic tapes.

It would be desirable to have such a system extended to other sites. A problem may lie in achieving compatability of hardware. One must also ensure that fertility indices are being calculated in the same way on each site. A possible way forward may be to set up a group to coordinate fertility experiments on a number of different sites. An overall fertility plan would almost certainly involve the construction of a large computer database. Database packages are still comparatively expensive and are often not feasible for use on microcomputers. However, a central mini or mainframe computer could easily perform the overall analyses.

REFERENCES

Esslemont, R.J. (1974). MELBREAD - Herd Health Recording Scheme Manual. Dept. Agric., Univ. Reading.

Roberts, S.J. (1971). Veterinary Obstetrics and Genital Diseases. 2nd Edition Roberts, Ithaca, New York.

Russell, A.M. and Rowlands, G.J. (1983). COSREEL - Computerised Recording System for Herd Health Information Management. Vet. Rec. 112 : 189-193.

Veeru (1980). DAISY - The Manual, VEERU, University of Reading

Walters, D.E. (1979). In Defence of the Arc Sine Approximation. The Statistician 28 : 219-222.

A STATISTICAL TECHNIQUE FOR QUANTIFYING SHORT TERM EFFECTS OF DISEASE ON MILK YIELD

S. LUCEY, G.J. ROWLANDS & A.M. RUSSELL

It has been claimed that disease causes loss of productivity from the dairy cow, yet few studies assess this accurately. Recently Lucey and Rowlands, (1983,1984), demonstrated that changes in the overall shape of the lactation curve, (using Wood's (1967) model), are associated with the occurrence of a number of diseases. A fitted curve from a cow's preceding lactation was used to estimate the expected shape of the same cow's next lactation, and by considering all cows, deviations from these expected curves were then used to assess changes associated with disease. The technique, however, did not take into account short term fluctuations in milk yield occurring in the weeks before or after diagnoses of disease. By using the curve fitted to the whole of the lactation, the method largely neglected any temporary deviations from the curve.

This paper describes a technique for assessing these short term fluctuations and the associated loss in milk yield. Fluctuations associated with ketosis and mastitis are used to illustrate the method.

MATERIALS AND METHODS

Data

Disease records and weekly recorded milk yields were used from 1,599 lactations resulting from calvings between July 1977 and June 1982. These lactations lasted for at least 15 weeks and occurred in 732 Friesian, Ayrshire and Holstein crossbred cows belonging to one of three dairy herds and two dairy units at the Institute. The data were collected using the COSREEL computerised livestock health recording system (Russell and Rowlands, 1983). All cases of disease observed by the stockman were notified to the Institute clinician. Feeding methods have been described in a previous paper (Lucey and Rowlands, 1984).

Statistical analysis

The mathematical model

$$y(n) = an^{b}e^{-cn}$$

was fitted by the method of maximum likelihood (Ross, 1980) to the milk records for each cow, with y(n) the milk yield at week n of lactation and a, b, c parameters in the formula of the lactation curve (Wood, 1967). The

* Agricultural and Food Research Council Institute for Research on Animal Diseases, Compton, Newbury, Berkshire.

effects of week of sampling and month of calving on milk yield were also taken into account in the analysis as shown by Rowlands, Lucey and Russell (1982).

Residuals, r, of the deviations of recorded weekly yields from each of these curves were derived for nine weeks prior to the week of diagnosis, for the week of diagnosis, and for ten weeks after diagnosis. The residuals, r, were then corrected for the average systematic deviations in recorded weekly yield from the fitted curves which occur during the lactation (Rowlands *et al.*, 1982). These systematic deviations from the fitted curve are shown in Fig. 1. The fitted curve is poor at describing the early rapid rise to peak yield, tending to overestimate milk yield up to peak yield and to underestimate peak yield itself. Thereafter mean weekly yields oscillate about the fitted curve.

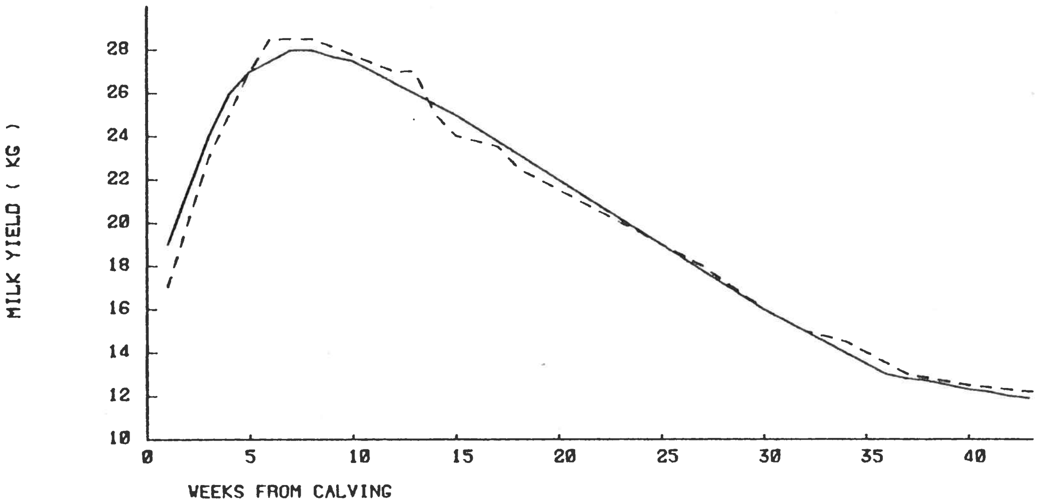


Fig. 1 Deviations in the mean observed milk yield (---) from average fitted values obtained using Wood's (1967) model of the lactation curve (——) (Rowlands *et al.*, 1982)

After correction, the data were collected together for cows with each disease category in turn and the model $r_{ij} = w_i + e_{ij}$ fitted to estimate the average weekly deviation w_i ($i= -9,-8,\ldots,0,\ldots,10$) with r_{ij} the residual for the jth cow in the particular disease category, i weeks from the diagnosis.

RESULTS

Deviations from fitted curves are shown in Figs. 2 and 3 for the weeks before and after disease diagnosis. Ketosis was associated with declines in milk yield prior to the week of diagnosis, but, following treatment at week 0, milk yield rose (Fig. 2). The differences in yield obtained by comparing the milk yield one week before with that one week after treatment are given in Table 1. Cows gave 5kg per day more milk for ketosis at the end than at the beginning of this 2 week period. It is interesting that yield appeared to decline at least 4 weeks before clinical diagnosis was made.

The size of short term fluctuations in milk yield which occurred with the diagnoses of clinical mastitis depend on the stage of lactation when the disease occurred (Fig. 3). Little deviation from the fitted curve was observed when mastitis occurred before peak yield. Interpretation of results in this early stage of lactation is difficult, however, because of the inadequacies of Wood's (1967) lactational model in these early weeks (Rowlands *et al.*, 1982). In contrast the occurrence of mastitis in later lactation was

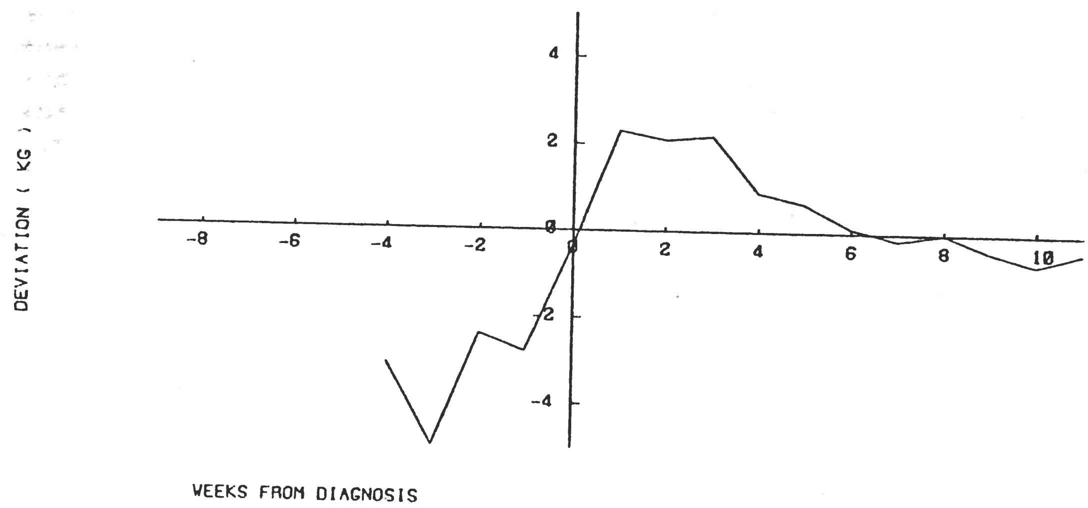


Fig. 2 Average deviations in milk yield from the fitted curve during the weeks before and after diagnoses of clinical ketosis

associated with fluctuations in milk yield similar to those observed for ketosis. Cows gave 2 to 3kg per day more milk one week after than one week before clinical diagnosis (Table 1). Milk yield appeared to be on the decline for two to possibly three weeks before clinical diagnosis was made (Fig. 3).

DISCUSSION

A diagrammatical illustration is given in Fig. 4 of how the above fluctuations in milk yield may be used to evaluate the total loss of milk yield over the period around the occurrence of a disease. If the model is refitted omitting data during the weeks prior to disease diagnosis the curve would take a slightly different path. The shaded area in Fig. 4 thus measures the amount of milk lost.

Figure 2 shows that in the weeks before treatment, milk yield is depressed by up to 5kg per day for cows with ketosis. This depression occurs for at least two weeks prior to diagnosis, resulting in a total loss in yield of approximately 60 to 70 kilograms in this two week period. Lucey and Rowlands (1983) demonstrated using the fitted curves that there was no significant reduction in 305-day yield associated with the occurrence of ketosis. This indicates that the short term fluctuations are the only losses of milk involved and that after treatment a cow will return to full milk production. The loss in milk yield observed agrees with losses reported by Cobo-Abreu *et al.*, (1979) who demonstrated reductions of about 100kg per lactation for lactations in which clinical ketosis occurred. The loss of 454kg of milk reported by Littledike *et al.*, (1981) was much larger. However, they give no description of how this value was obtained.

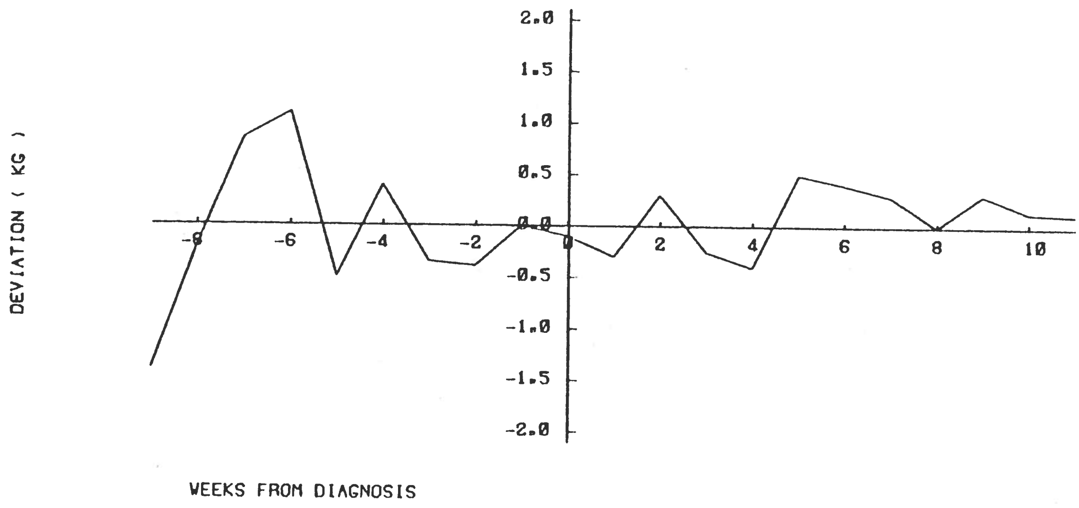


Fig. 3a Average deviations in milk yield from the fitted curve during the weeks before and after diagnoses of clinical mastitis which occurred before the week of peak yield

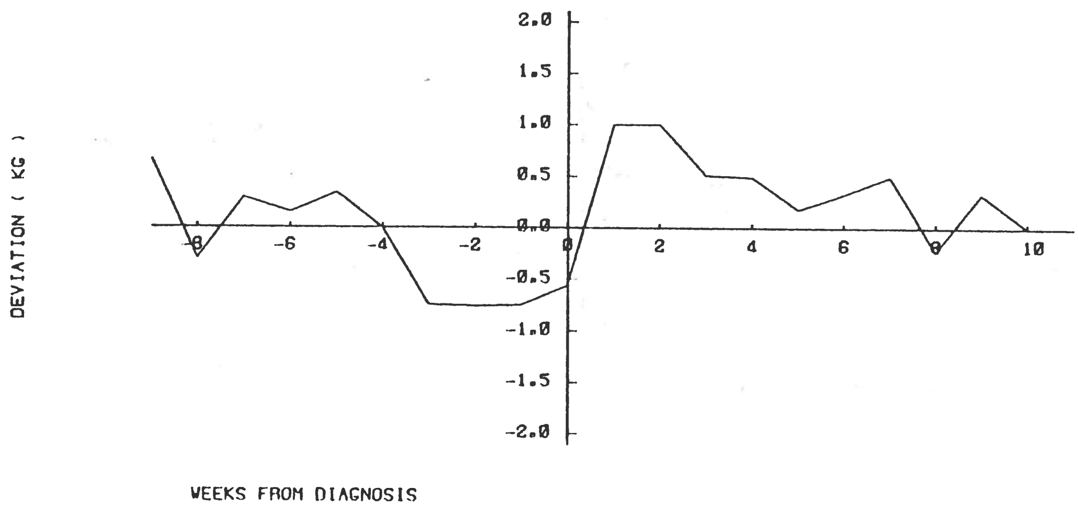


Fig. 3b Average deviations in milk yield from the fitted curve during the weeks before and after diagnoses of clinical mastitis which occurred between peak yield and 10 weeks after peak yield

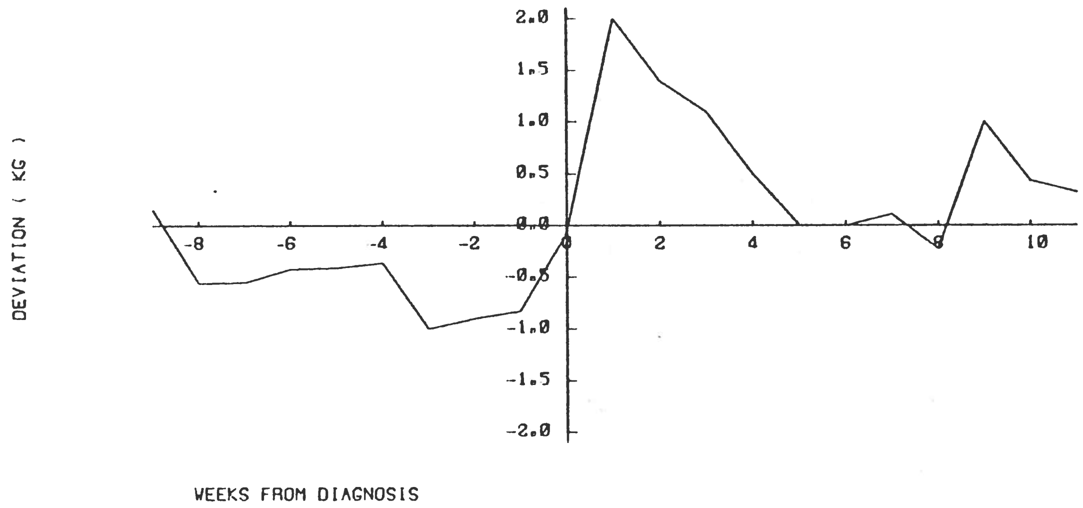


Fig. 3c Average deviations in milk yield from the fitted curve during the weeks before and after diagnoses of clinical mastitis which occurred between 10 and 20 weeks after peak yield

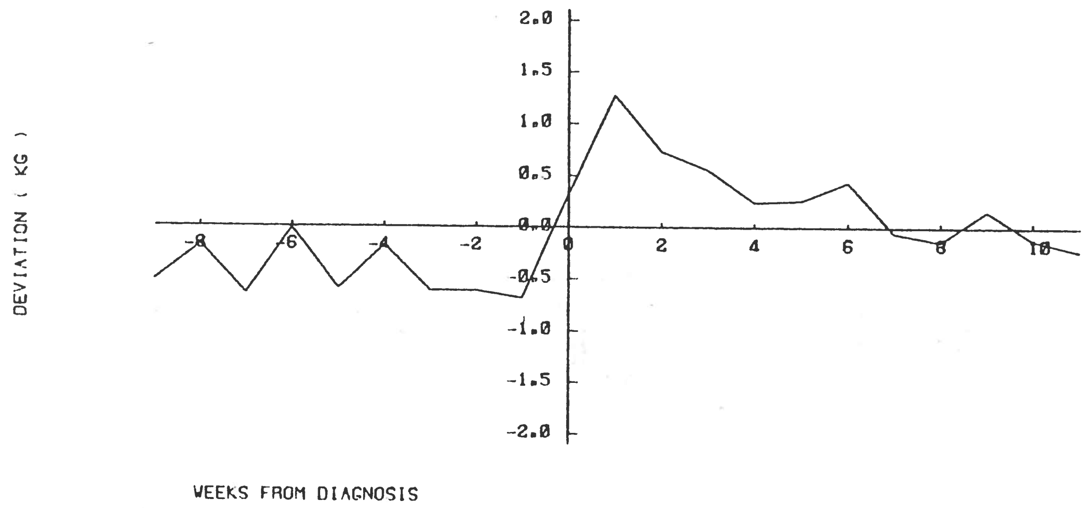


Fig. 3d Average deviations in milk yield from the fitted curve during the weeks before and after diagnoses of clinical mastitis which occurred more than 20 weeks after peak yield

Short term changes in milk yield were associated with mastitis when the clinical diagnosis was made after the week of peak yield. Gilda and Grant-Moody (1959) reported a decline of milk yield 24 hours before the appearance of clinical symptoms whereas the results from this study indicate that milk yield began to decline much earlier, possibly as much as three weeks before clinical symptoms were diagnosed. This resulted in a loss in yield of between

35kg and 60kg depending on the stage of lactation at which the mastitis was diagnosed.

Table 1 Comparison of the mean deviation of recorded milk yield from fitted lactation curves one week before diagnosis with those one week after diagnosis

	Number of diagnoses	Deviation (kg/day) before	Deviation (kg/day) after	Difference (kg/day)	S.E. of difference between deviations
Ketosis	91	-2.8	2.3	5.1	0.80
Mastitis:					
Before peak yield	256	0	-0.3	-0.3	0.41
Peak yield to 10 weeks after peak yield	143	-0.8	1.0	1.8	0.38
10-20 weeks after peak yield	90	-0.8	2.0	2.8	0.47
More than 20 weeks after peak yield	66	-0.7	1.3	2.0	0.43

Previous studies (Lucey and Rowlands, 1984) have shown that mastitis is associated with overall changes in the shape of the lactation curve in addition to the short term fluctuations found in this study. Mastitis before peak yield, although showing little influence on production in the short term, was found to reduce peak yield. Subsequent 305-day yield was also reduced by approximately 500kg. No significant changes in curve shape were observed when mastitis was diagnosed after peak yield. However, 305-day yield was reduced as cows with mastitis tended to have shorter lactations. The results of this study combined with those of Lucey and Rowlands (1984) indicate that when mastitis occurs before peak yield, recovery is incomplete and yield is depressed for the remainder of the lactation. Mastitis after peak yield, however, is associated with only a short term reduction in milk yield with yield returning to normal soon after treatment.

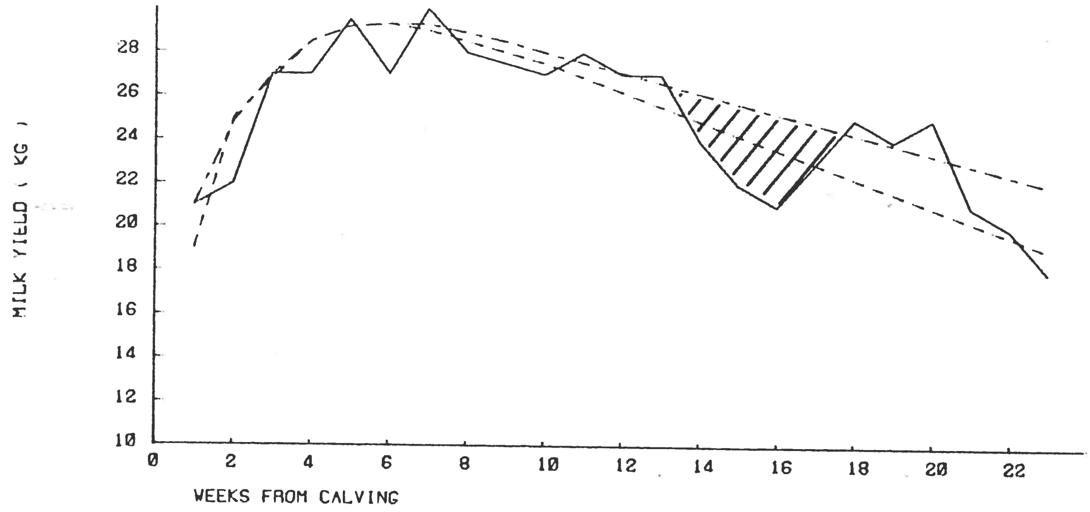


Fig. 4 Diagrammatical illustration of the effect of disease on milk yield showing the fitted lactation curve (Wood, 1967) fitted to the complete set of weekly records (---) and the same lactation curve if the weeks immediately preceding diagnosis are omitted (-·--·-). The shaded area represents the temporary reduction in milk yield due to disease.

REFERENCES

Cobo-Abreu, R., Martin, S.W., Willoughby, R.A. and Stone, J.B. (1979). The association between disease, production and culling in a university dairy herd. Can. Vet. J. 20, 191-195.

Gilda, G. and Grant-Moody, E. (1959). Mastitis studies in a dairy herd. J. Dairy Sci. 42, 740.

Littledike, E.T., Young, J.W. and Beitz, D.C. (1981). Common metabolic diseases of cattle : ketosis, milk fever, grass tetany, and Downer cow complex. J. Dairy Sci. 64, 1465-1482.

Lucey, S. and Rowlands, G.J. (1983). Relationships between production disease and milk yield. Proc. of the Fifth International Conference on Production Disease in Farm Animals, Uppsala, Sweden, 1983.

Lucey, S. and Rowlands, G.J. (1984). The association between clinical mastitis and milk yield in dairy cows. Anim. Prod. (in press).

Ross, G.J.S. (1980). Maximum likelihood program. Lawes Agricultural Trust, Rothamsted Experimental Station, Harpenden, Hertfordshire.

Rowlands, G.J., Lucey, S. and Russell, A.M. (1982). A comparison of different models of the lactation curve in dairy cattle. Anim. Prod. 35, 134-144.

Russell, A.M. and Rowlands, G.J. (1983). COSREEL - a computerised recording system for herd health management. Vet. Rec. 112, 189-193.

Wood, P.D.P. (1967). Algebraic model of the lactation curve in cattle. Nature 216, 164-165.

Printed at the University of Edinburgh