

TRACKING THE COURSE OF A VIRULENTLY CONTAGIOUS DISEASE: THE FOOT AND MOUTH EPIDEMIC IN THE UK, 2001

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Abstract: The United Kingdom is in the grip of one of the most serious animal health crises it has ever experienced. Foot and mouth disease has raged since February 2001 and at the time of writing (July 2001) it is still limiting the movement of animals and the activities of farmers over much of the country. Due to the development of rapid communication technologies and geographic information systems, it is possible to monitor and analyse the course of this disease in real time. At the Royal Agricultural College the data published daily by the Department for the Environment, Food and Rural Affairs (DEFRA) is being visualised and published on the internet, both as a source of daily information for the farming communities and the general public and as a means of examining the pattern of development and movement of the disease. This allows underlying patterns in the outbreak to be seen as they develop, rather than after the resolution of the epidemic. This work has highlighted a number of points: the difficulty to establishing both the exact location and time of confirmation of a particular case of the disease; problems that can arise when base maps used for monitoring national problems are not up to date; the difficulties caused by aggregation of data into different geographical domains, the propagation of confusion that can arise from publishing inaccurate or unconfirmed data. This work has generated considerable international interest, with the directory of information being accessed from outside of the College more than 62,000 times in the last five months. By the date of the conference (November 2001) it is hoped that the epidemic will effectively be over and that the complete database on the disease will be ready for presentation and examination.

INTRODUCTION

In February 2001 several cases of foot and mouth disease were detected in the United Kingdom, first at an abattoir in south east England and shortly after in a number of locations throughout the country. Within days of these initial outbreaks related cases arose in Ireland, France and the Netherlands. The wide geographical spread of these early cases and the speed of its movement was unprecedented, leading to concerns, yet to be fully addressed, that the disease had been established in the UK before it had been detected in February 2001. The rapid and wide geographical spread of the disease has made it very difficult to contain and eradicate. Even at the time of writing (July 2001) new cases are arising in a number of regions, despite a government implemented programme of culling and destruction of all diseased and suspect livestock. The number of confirmed case is over 1,800; the number of farms where all livestock has been slaughtered is over 8,700; the total number of slaughtered animals is over 3.5 million. (DEFRA 2001 a)

After initial public support there has been widespread concern that the policy of slaughter is failing to achieve the eradication of the disease and that its implementation is both inhumane (Swindell 2001) and unnecessary (Winter 2001, Woods 2001). There has been growing public opposition to this policy, with some farmers refusing to cooperate

with government officials, leading to cases of farmers barricading their land to prevent the entry of slaughter men. These feelings increase daily as new reports are published of mass slaughter of healthy animals due to movement restrictions and the welfare problems that these restrictions create:

Sheep farmers have warned of a new crisis that could lead to the slaughter of three million "light lambs" that have no market because of foot-and-mouth restrictions.... Most of the lambs would have been exported, but exports have been banned since February. Putting the lambs on the market at home would mean a catastrophic drop in price.

BBC news online July 14, 2001
http://news.bbc.co.uk/hi/english/uk/newsid_1438000/1438728.stm

The Ministry of Agriculture, Food and Fisheries (now subsumed into the Department of Environment, Food and Rural Affairs - DEFRA) adopted the widely praised policy of publishing all current information about the epidemic on its website. This enabled the public to see the progression of the disease. As it became clear that it would not be

contained and overcome quickly, as had first been hoped, the quality and reliability of this data came under scrutiny.

At the Royal Agricultural College (RAC) we have carried out particular studies of the geographic and temporal spread of the disease, based on the DEFRA data, which are discussed in this paper. Because the epidemic is still running, and is likely to do so into the foreseeable future, this must be regarded as a working paper rather than a definitive study.

1 REAL TIME MONITORING OF DISEASE PROGRESSION

The first case of foot and mouth disease was detected at an abattoir in Essex, south east England, on February 20, 2001. Almost immediately further

cases were found on neighbouring farms. The sources of all animals at the abattoir were traced, which produced evidence that the disease had been present on a farm in Tyne-and-Wear, north east England, for at least two weeks prior to the first detection. On February 24, the disease was found in Devon, south west England, on February 27 in Anglesey, north west Wales, on February 28 in Cumbria in north west England and on Mar 1 in Dumfries and Galloway in southern Scotland. (Fig. 1) Within this time span the disease had appeared in seven other counties in England as well.

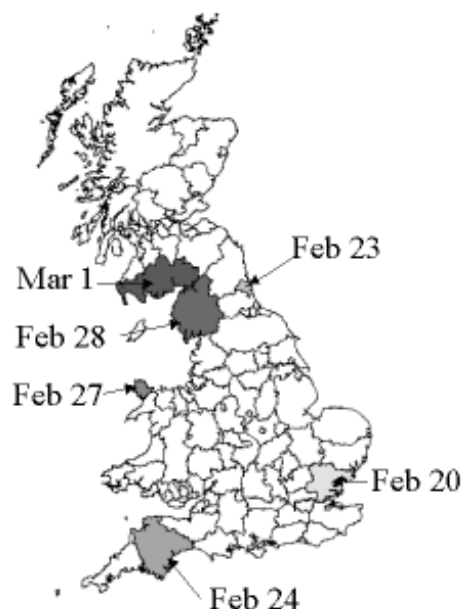


Figure 1 Known limits to the spread of the disease in first ten days in Great Britain
source DEFRA 2001(a)

Related cases broke out in Northern Ireland, the Republic of Ireland, France and the Netherlands, all of which were brought under control relatively quickly. The cases in France raised significant concerns as sheep there, imported from Wales and apparently healthy, were found to have antibodies to the foot and mouth virus. This gave strong indication that the disease was present in the United Kingdom from well before it was detected in Essex, or from when it may first have arisen on the farm in Tyne-and-Wear, the oft cited source of the epidemic (DEFRA d).

In addition to the geographic spread of the disease, the virulence of the infection lead to a very rapid

increase in the number of new cases occurring each day (fig. 2). This meant that people trying to contain the disease were overwhelmed not just by its geographic spread, but also by the sheer number of cases. According to analysis at the RAC, a total of 36 counties had cases, with the maximum number recorded on any one day being 59 on March 30, 2001. (These figures do not agree with those published by DEFRA because of the ministry changed the definition of reporting periods during the epidemic on at least two occasions and they located cases in the wrong counties in several known instances, which are discussed below.)

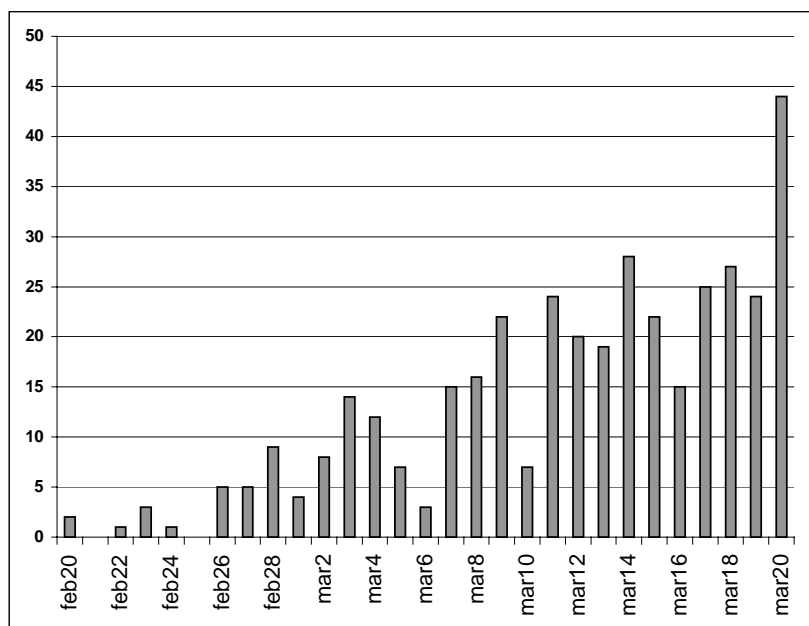


Fig2 Number of new cases per day in the first month (382 cases in total)
source DEFRA 2001 (a)

2 SOURCES OF DISEASE DATA

The RAC decided to use the statistics officially published by DEFRA on its internet web site as its sole data source (DEFRA 2001 a), deeming these to be the most reliable available. Some livestock consultants amended their own data by use of other sources, such as their own staff reporting their interpretation of confirmed cases from farm visits. Reliance on government figures does not ensure absolute accuracy for a range of reasons, some of which are discussed in detail below. There has been even confusion over the definition of "confirmed cases" of foot and mouth disease. In many instances, cases which were deemed confirmed on the expressed opinion of a visiting veterinary surgeon later proved negative after blood tests. These false-positives were not removed from the ministry's lists of confirmed cases for the following stated reasons:

How are new Cases recorded?

As soon as a case of foot and mouth is confirmed, it is then included in the overall national figure. Should the subsequent laboratory test prove negative, this case will not be removed from the national figure. A negative test result does not necessarily mean that the animal was not infected. For instance, if the disease is old,

the virus may not be present in the sample collected. In animals that have been recently infected, blood tests may prove negative for antibodies.

Source of quotation DEFRA 2001 (b) accessed July 24, 2001

This policy of retaining tested negative cases in the statistics of confirmed cases raises concerns that either the blood tests are unreliable, or that the government does not wish to highlight the number of potentially false diagnoses which resulted in unnecessary slaughter.

The government instigated a policy of culling all livestock on contiguous farms (those which shared boundaries) with those having confirmed cases, to create a sterile buffer around every case. This meant that many incubating cases were destroyed. Whilst this was the intended purpose of the contiguous cull, it means that the true extent of the epidemic will never be known.

Further problems with the published data concerned the manner in which location and time of occurrence of a cases were defined. These problems can seem trivial in some contexts, but solutions exist and should be used. The errors generated by these unaddressed problems lowers confidence in the data to a point where it is felt to be quite unreliable

3 DEFINING THE TIME OF OCCURRENCE OF A CONFIRMED CASE

DEFRA has published the time of occurrence of a confirmed case in at least three ways during the course of this epidemic. Firstly, it published the number of cases confirmed on any one calendar day, and this date is still recorded in its complete list of all cases. Some weeks into the epidemic it changed its official reporting period from a calendar date to "the 24 hour period running from 19:00 on one day to 19:00 the following day". This meant that when the ministry announced a certain number of cases had occurred on a particular day, these cases may, and sometimes were, spread over two calendar dates. This is one reason why the number of daily cases reported in different sources may vary. It also means that some authorities cite different dates as the peak of the epidemic.

After the general election in the United Kingdom on June 7, 2001 (which had been postponed from May 3 because of the foot and mouth epidemic), the newly formed Department of Environment, Food and Rural Affairs (DEFRA) announced that in the reporting period for confirmed cases would be from 17:00 on one day to 17:00 the following day. The reasons given were the workload on their staff and, rather curiously, the youthfulness of some of that staff. As the number of daily cases had fallen to single figures by this time, the reasons given for the change are somewhat strange. The shift of the

reporting period forward by two hours into the working day means an increased likelihood of cases being announced on certain days when they actually occurred on the previous day. For example, it was announced that there were 10 reported cases on July 18, the first day with cases in double figures for over a month, and as such, reported widely in the press. This figure is still shown in the summary statistics. There were in fact only 9 cases that day, the tenth had occurred after 17:00 on the previous day, July 17. Nine cases would not have been reported as headline news.

4 VISUALISING THE TEMPORAL DEVELOPMENT OF THE EPIDEMIC

At the RAC we have dealt with the problems of visualising the temporal development of this epidemic in two ways. First, we record the number of confirmed cases as published by DEFRA (2001 c) against the date entered in the complete list of confirmed cases as a simple bar chart. Secondly these figures are smoothed using a one week moving average equation. This means that the number of cases shown for each given date is the mean number of confirmed cases for the seven day period running from three days before that date to three days after. This moving average is used to show the influence of both the proceeding three days and the subsequent three days. This moving average is plotted as a curve on the bar chart (figure 3).

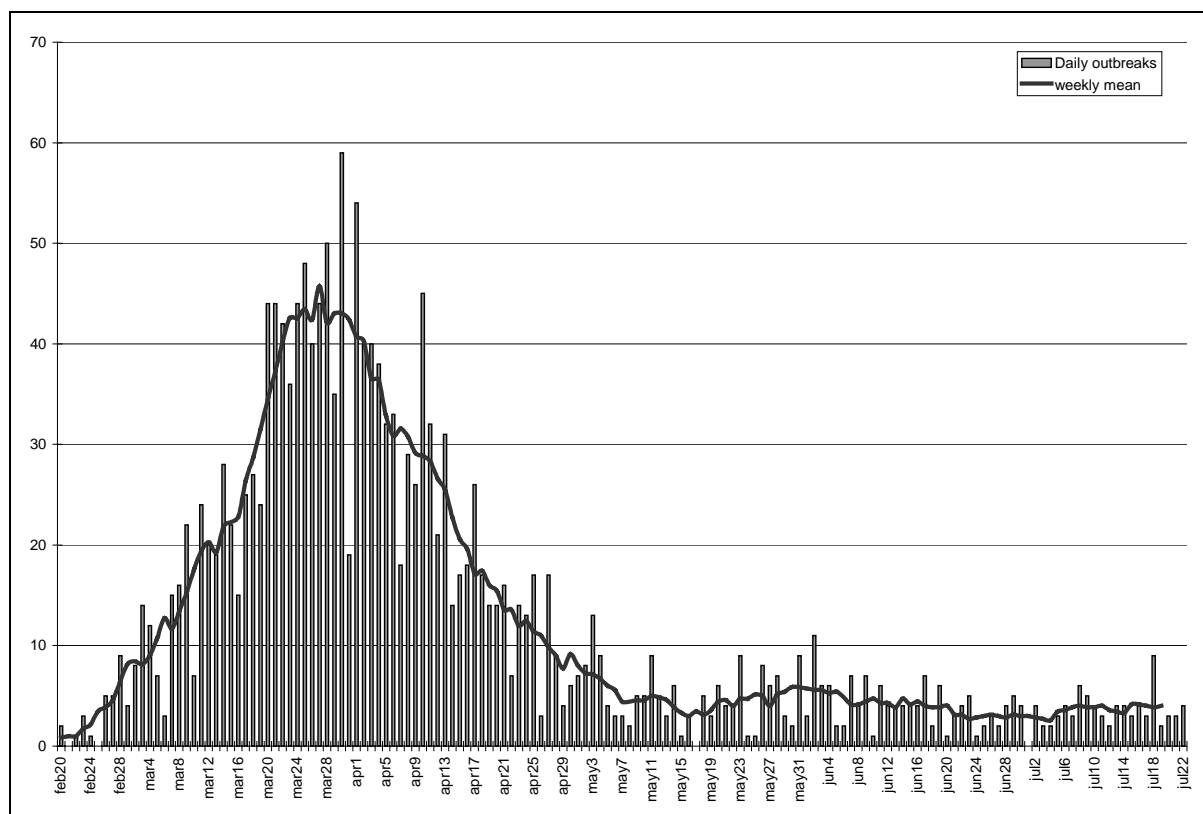


Fig3 Daily cases and weekly smoothed figures from Feb 20 to July 22, 2001

We feel this gives a more accurate view of the intensity of the epidemic than either the daily number of cases, or the average daily number of cases per week. The daily figures show enormous fluctuations. On March 30 there were 59 cases recorded. On March 31 there were 19 and on April 1 a total of 54. The disease was not waxing and waning dramatically over these three days. These differences are due to tired, over-worked and over-stretched people leaving one day's reports till the next morning. The moving average shows what the weekly mean number of daily cases is for *each day*, and this is a closer indication of how many cases there were on any day than the actual recorded figures for that day. It is interesting to note that although the epidemic is often stated as having peaked at 59 cases on March 30, the weekly smoothed figures indicate that it peaked at 46 cases on March 27th, three days earlier.

These weekly smoothed figures also show that the intensity of the epidemic dropped rapidly from this peak of 46 cases per day on March 30th, to 4 on May 7th and then has carried on at this intensity until the date of writing (July 22, 2001), rising to a maximum of 6 and falling only to a minimum of 3 during this time period. This steady number of cases is being increasingly referred to as the "long tail" of

the epidemic in the mass media and raises public concern that the disease is resisting eradication.

5 THE SPATIAL DISTRIBUTION OF THE EPIDEMIC

The temporal progression of the epidemic is one important factor in its nature. The other is its spatial distribution, referred to in outline above. It was the wide geographical spread of the early cases which have lead directly to the enormous problems in tackling this epidemic. Resources could not be concentrated in one area, neither could sterile zones be established as "fire-breaks". The disease broke out in new locations daily. The first case was noted on February 20th. By March 1st there had been cases in 15 counties right around the country. For the first few weeks DEFRA attempted to trace each case back to its probable progenitor (DEFRA e). After several months of outbreaks, this became quite meaningless.

Understanding this spatial distribution was of vital importance, but visualising it proved remarkably difficult, using the published date. The published locational information was poor during the early stages of the epidemic, although it has improved in some later cases. In the most recent 10 cases, 4 had post codes (area references), 2 had

alphanumeric grid references (point references, but non-Cartesian) and the remaining four only had descriptive addresses. Only one postcode reference was given in the first 1400 recorded cases, whilst in the last 500 they have been common but not universal. The first alphanumeric grid reference was

given for case number 1489, but even after that they have been rare. The only consistent spatial reference in every case has been to the county and this has been the basic unit that the RAC has used for mapping the daily location of every case (fig 4.).

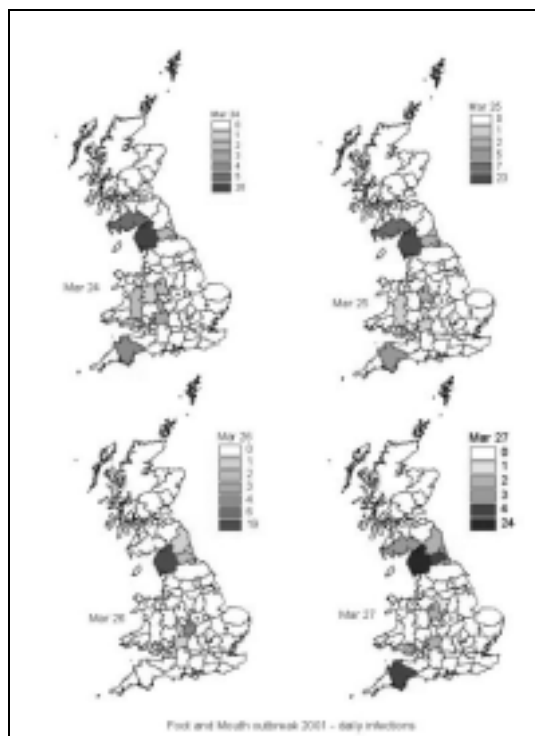


Fig4 Daily cases in each county, Mar 24 - 27, 2001

Unfortunately, even using counties as spatial units has proved problematic. The local authority boundaries in England, Scotland and Wales (which constitute the islands of Great Britain) have undergone a great number of changes over the last few decades, with the last major re-organisation taking place in 1996-97. This has resulted in the boundaries of some counties changing, new local authorities being established and some previous ones disappearing.

This confusion has been exacerbated by DEFRA. In their overall listings of confirmed cases they refer to pre-1996 counties, many of which no longer exist. However, in their individual lists of confirmed cases in each county they use the correct contemporary counties, with the cases reallocated. Why this confusion between historic and contemporary counties exists is unclear particularly within a government ministry.

These problems with county locations have been increased in some cases where the assignment to a

county has simply been wrong. In one case at least this has come about through the well known geographical problem of using different, non-congruent areal units for determining location. In this case, a farm fell in a postcode district, HR3, which is associated with the county of Hereford in England by its two leading letters (HR). The case was therefor listed as being in the county of Hereford. However, the postcode area actually overlaps county boundaries, and this particular case was in fact in Powys in Wales (figure 5).

These errors may appear minor but they lead to lack of confidence in the data, and when some areal units are large (and some rural counties are *very* large), they give little idea of the true location of the disease. DEFRA have published maps showing the point locations of cases, but the coordinates of these points are not given. The recommendation in this paper is that this is how location should be defined if the information is to be of practical use in monitoring the disease.

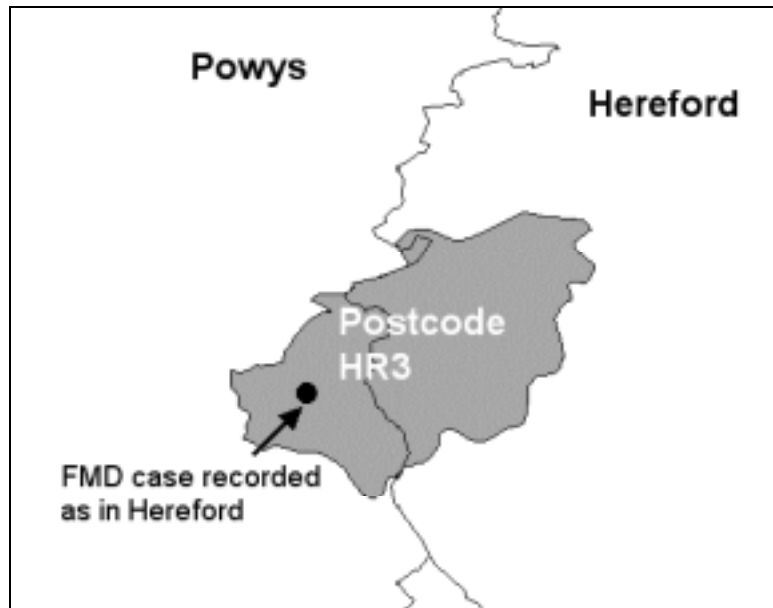


Fig5 Case recorded in the wrong county on basis of unrelated areal unit

6 PROBLEMS OF DATA AGGREGATION

The problems raised by confusion between former and current administrative boundaries are not confined to just defining the location of disease cases. In order to gain in-sight in to the seriousness of the epidemic, it is important to be able to compare disease statistics with overall farm statistics. At the RAC we were interested in checking what percentage of livestock farms had been infected in each county. Agricultural census figures are collected regularly, in great detail. However, in some areas these have been aggregated into regions which do not correspond with contemporary counties. For example, there was a serious outbreak of foot and mouth disease in the Island of Anglesey, off the north west coast of Wales. Unfortunately, farm statistics for Anglesey are grouped with those of several neighbouring counties into one set for “North West Wales” making it impossible to gauge the seriousness of the disease in that area. There is also concern that the census will relate to historic county regions and not contemporary ones. This is beyond the control of DEFRA, but does show that changes to administrative units in a country can have serious consequences for long term national planning.

7 VISUALISATION OF THE PROGRESSION OF THE EPIDEMIC

This epidemic is different from earlier ones in that it has occurred after the creation of the internet as a medium of almost instant information

dissemination and after the development of powerful geographical information systems (GIS) which can be used to analyse any spatial component of this information. Subject to all of the provisos about data quality given above, information on the time and location of confirmed cases of the disease has been made available to the public in near real-time via the DEFRA website. This has allowed independent researchers all over the world to study and comment of the progression of this epidemic as it happens. At the RAC we hoped to use GIS to study the pattern of the disease development both as a pure research project and with the hope that if discernable patterns with identifiable causation could be detected, this could aid in tackling the epidemic.

In reality, no such pattern has emerged. As mentioned earlier, the disease had become so wide spread before it was even detected that it was impossible to build any form of network or development model that was in any way predictive of future cases. DEFRA attempted to carry out a similar study by noting causative links between early cases, but not only were these links often very speculative, the patterns which emerged were chaotic and simply showed that there was no order or sequence to outbreaks. (DEFRA 2001 e)

As a further attempt at visualisation, we explored the idea of creating animated maps of the country showing daily cases over an extended time period. The output was unscientific, but did highlight disease “hotspots“ in a dramatic manner. Certain counties appear repeatedly, with a darkness of colour representing the number cases. At the same

time, counties flash in and out of the map from nearly all parts of the country. It is clear that this was a national epidemic, with some regions experiencing almost total devastation. The stages of this animation are being published on the RAC web site (RAC 2001)

8 PUBLIC INTEREST IN PUBLISHED INFORMATION

As soon as this work started at our College, we decided to publish the results on the internet (RAC 2001). The primary purpose was to allow our students and staff to have easy access to the information. To our surprise there was an enormous public interest in the work, with the resource being accessed over 62,000 times to date from outside the institution. To aid the public in following the results, we try to give a simple commentary on what is happening. This work has been quoted both in the broadcast media (*Channel 4 News* in the UK) and in some newspaper reports. The resource has also been linked to from the Institute of Animal Health in the UK (URL needed) and the Federation of American Scientists (FAS) in the USA (URL needed). In the latter case, the comment was made by the FAS web master that they regarded the RAC presentation of the epidemic data as more useful than the official government sites.

9 THE CURRENT STATE OF THE DISEASE AND RECOMMENDATIONS

As stated, this paper represents work in progress and there is little indication that we are anywhere near a position from which we can look back over the whole epidemic in order to draw conclusions and make plans for dealing with the inevitable next one. Just today (July 25, 2001) it has been announced that antibodies to the FMD virus have been detected in large number of free-ranging sheep which graze the mountains in Wales. Containing the disease within this type of environment is all but impossible, short of destruction of the entire national herd. Not only is this a horrifying prospect economically (Harvey 2001), the public at large are increasingly unhappy about the policy of mass slaughter, and the problems of disposal of the carcasses is becoming insuperable. What started as a non-fatal animal health problem is becoming a matter of public health concern through environmental contamination caused by the disposal methods (burning and burying).

We cannot make recommendations on tackling the disease or its consequences. Other authorities and institutions are dealing with that. What we

would recommend is that modern technology is fully exploited in the recording of the disease to make the data more reliable and thus more useful. It would also increase public confidence in the official response to the epidemic. The recommendations we would make are that time and location of cases are recorded as discretely as possible, and not aggregated into larger units. This can be done through the use of simple, handheld Global Positioning Systems (GPS) technologies. Equipping all veterinary officers with a GPS recorder will allow them to record the Cartesian or geographic coordinates of each outbreak, and the exact time they were diagnosed. Researchers and officials could then choose to aggregate these data into any time units and locational units which are most useful to them. It would also greatly reduce the work and speed up the collection data, which is vital when dealing with what is considered to be one of the most virulently contagious diseases in the world.

References

Note concerning British Government departments:

The Ministry of Agriculture, Food and Fisheries (MAFF) of England and Wales was dissolved after the UK general election in June 2001 and its responsibilities were taken over by the newly formed Department of Environment, Food and Rural Affairs (DEFRA). This means that there will be a period when the abbreviations MAFF and DEFRA will be interchangeable and equivalent.

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