

SCIENCE DIRECTORATE

DEFRA

Department for
**Environment,
Food & Rural Affairs**

**Foot and Mouth Disease
Modelling Workshop
23 May 2002**

Summary Report

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DEFRA
Department for
**Environment,
Food & Rural Affairs**

FMD MODELLING WORKSHOP

AGENDA

23 May 2002

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| Chair | Prof. Howard Dalton, DEFRA | |
| 9.00-9.20 | Coffee | |
| 9.20-9.30 | Introduction | Prof. Howard Dalton, DEFRA |
| 9.30-11.00 | Use of mathematical models during the 2001 FMD outbreak | |
| 9.30-10.00 | The use of the Interspread Simulation Model during the 2001 FMD outbreak | Prof. John Wilesmith, VLA |
| 10.00-10.30 | Epidemiology of FMD epidemics: past work and future priorities | Prof. Neil Ferguson, Imperial College |
| 10.30-11.00 | The foot and mouth outbreak: models, risks and heterogeneities | Dr Matt Keeling, Warwick University |
| 11.00-11.20 | Coffee | |
| 11.20-12.50 | Views of people involved in controlling the 2001 FMD outbreak, DEFRA policy, and collection and use of farm data for modelling | |
| 11.20-11.50 | Role of IAH in the 2001 epidemic - input of experimental data into models, current FMD spread models, strengths & weaknesses of the models | Dr Alex Donaldson, IAH |
| 11.50-12.10 | How modelling advice was used in the 2001 outbreak and how models could be improved to assist with policy decisions in the future | Mr Fred Landeg, DEFRA |
| 12.10-12.30 | FMD control and models | Mr Sam Mansley, DEFRA |
| 12.30-12.50 | Modelling animal diseases - data issues | Dr Richard Clifton-Hadley, VLA |
| 12.50-13.40 | Lunch | |
| 13.40-16.00 | Discussion session | Chaired by Prof. Howard Dalton & Dr Nick Coulson, DEFRA |

**FOOT AND MOUTH DISEASE
MODELLING WORKSHOP**

23 May 2002

The aim of the workshop was to bring together for the first time experts from a range of disciplines, to discuss research needs for modelling foot and mouth disease (FMD) and other exotic animal diseases.

The workshop was divided into two sections. The first section consisted of a series of presentations, addressing the use of mathematical models during the 2001 FMD outbreak, the views of people involved in controlling the outbreak, DEFRA policy, and the collection and use of farm data (pages 5-43). The second section consisted of an open discussion, covering areas such as database development, modelling requirements, funding, and collaboration among experts (pages 44-50).

On the basis of the presentations and the discussion session, a series of recommendations have been made on how we should proceed (page 51).

PRESENTATIONS

The Use of the Interspread Simulation Model During the 2001 FMD Outbreak

Prof. John Wilesmith

Veterinary Laboratories Agency, Weybridge

Overview

The development of the Interspread Simulation Model (ISM), and its subsequent use during the 2001 FMD outbreak was described. The ISM uses information on the epidemiology of FMD (from past outbreaks and laboratory studies) to predict the potential spread of the disease. In the 2001 outbreak it was used to predict several valuable epidemiological parameters, including the likely number of unrecognised cases, the potential spread and duration of the epidemic, and the intensity of outbreaks which had already occurred. In addition, it was used to analyse several FMD control measures (including culling and vaccination strategies). Potential problems of the ISM were also described, and these included the complicated nature of the program and the need to incorporate economic issues. In the future, the ISM could be used to investigate control measures at a local scale, while more detailed information on demographics, animal movements and disease patterns could further improve the predictions.

Epidemiology of FMD Epidemics: Past Work and Future Priorities

Prof. Neil Ferguson, Dr Christl Donnelly & Prof. Roy Anderson

Imperial College of Science, Technology & Medicine

Overview

The involvement of the Imperial College team in the 2001 FMD outbreak was described. Their participation was prompted by concern over the initial delays in slaughtering infected premises, as well as academic curiosity. Their aim was to provide independent scientific advice to the government on effective control measures. Initial analyses used a simple implicitly spatial model, capable of modelling FMD spread at a national and regional level. The model was used to simulate the impact of different control strategies. Culling animals on infected premises and contiguous premises within 24 and 48 hours respectively was predicted to be highly effective, while vaccination was predicted to be less effective. Later analyses involved a spatial hazard model and looked at factors influencing the spatio-temporal spread of the epidemic. Species mix, animal numbers and farm fragmentation were identified as important factors influencing risk at the farm level. In addition, it was found that the epidemic could have been reduced in scale if culling measures had been implemented earlier. Future research topics relating to database creation, experimental work and modelling were also discussed.

The Foot and Mouth Outbreak: Models, Risks and Heterogeneities

Dr Matt Keeling¹, Prof. Bryan Grenfell² & Prof. Mark Woolhouse³
¹Warwick University, ²Cambridge University, ³Edinburgh University

Overview

The model of the 2001 FMD outbreak developed by the Cambridge (& others) team was described. To take account of the spread of the epidemic through a heterogeneous landscape, they developed an individual farm-based stochastic model. The model was used to assess the performance of a range of control methods (e.g. culling, and prophylactic and reactive vaccination etc.). It was suggested that in the future it would be valuable to assess the effectiveness of more control options, covering a range of viral strains and invasion scenarios. Other suggestions included exploring the role of within-farm epidemics, using MCMC methods to re-estimate current parameters and explicitly estimate the kernel, and developing a GIS component containing road connections.

**Role of IAH in the 2001 Epidemic - Input of Experimental Data into Models,
Current FMD Spread Models, Strengths & Weaknesses of the Models**

Dr Alex Donaldson

Institute for Animal Health, Pirbright

Overview

The role of Pirbright in the 2001 FMD outbreak was described. This included characterisation of the virus, testing samples (for diagnostic and surveillance purposes), formulation of emergency vaccine stocks (500,000 doses), analysing the risk of virus spread (via the wind and from pyres), training staff, and providing information and advice to the government and others. Control options for FMD were considered and limitations in the model used to assist decision making during the 2001 outbreak were highlighted. In particular, the model did not take account of differences among species in the profiles of their infectiousness (e.g. pigs can excrete 60 times more airborne virus than sheep and cattle) and differences in the minimum dose required for infection. The consequences of the culling policy were also considered in terms of its strengths (e.g. reduction in density of incubating animals) and weaknesses (e.g. carcass disposal, violation of biosecurity measures etc.). It was indicated that future research should focus on the development of (a) a validated diagnostic test for use on the farm (b) a validated test to differentiate infected from vaccinated animals and (c) new vaccines. In addition, infectious profiles and transmission by different livestock species, as well as other factors influencing transmission need to be determined. Finally, fully validated models (wind spread and strategic) need to be developed.

How Modelling Advice was Used in the 2001 Outbreak and How Models Could be Improved to Assist With Policy Decisions in the Future

Mr Fred Landeg
DEFRA

Overview

The models used during the 2001 FMD outbreak were described. These included the Interspread Simulation Model (ISM) and air dispersion models. The ISM was used to estimate the number of undetected cases, investigate hotspot areas, and examine potential control strategies, while the air dispersion models made predictions about the short and long distance dispersal of the virus. It was suggested that in the future, a fully validated, transparent model, incorporating economic parameters should be developed, in conjunction with control authorities. However, further development of models based on the 2001 epidemic may be of little immediate use with regards to future outbreaks, which may have different characteristics.

FMD Control and Models

Mr Sam Mansley
DEFRA

Overview

FMD control objectives, options and outcomes were described. With regards to the 2001 outbreak, a stamping out policy (which has been developed over the last 100 years) was initially put in place. Subsequently, models were used to establish if alternative strategies should be implemented. However, the models contained incomplete data and lacked veterinary input. The consequences of employing these alternative culling strategies were discussed. It was indicated that greater communication between everyone involved in controlling an outbreak (e.g. vets in the field, modellers etc.) is required in the future. In addition, transparent easily understandable models should be developed, while improved core and field data are also required.

Modelling Animal Diseases - Data Issues

Dr Richard Clifton-Hadley

Veterinary Laboratories Agency, Weybridge

Overview

Issues relating to the collection, collation and availability of field data were discussed. In particular, suppliers of data have a range of responsibilities, including maintaining confidentiality and anonymity. In addition, the data provided should be accurate, cover the specified fields and time period, and be presented in an understandable format etc. Recipients of data also have responsibilities. For example, recipients need to provide clear specifications about the data they require, maintain confidentiality, and fulfil contractual obligations (e.g. only use data for specified purposes, return data when work is finished etc.).

DISCUSSION SESSION

DISCUSSION SESSION

Prof. Howard Dalton opened the discussion session. He started the debate by asking if models were needed at all and, if so, what type, and what data would be required?

The comment was made that a decision support system should be a priority, with models fitting into this system. In addition, there was general agreement that since there are many aspects to the control of a major disease outbreak, a 'family' of models is needed to address all the issues.

The problems of trying to develop and use models during the crisis of an epidemic were recognised and it was agreed that development and testing of models should proceed during disease-free periods. It was suggested that not enough emphasis had been placed on drawing in information and advice from those with field experience of controlling the outbreak.

Dr Nick Coulson then chaired the remainder of the session, which incorporated a series of prepared questions:

1. Data and databases

Questions

- How can the collection and availability of field data be improved?
- Was sufficient data collected during the FMD outbreak or was some essential data missing?
- Is data collection inevitably hindered by the necessity to eradicate the disease as quickly as possible?
- Was the data provided for the modelling systems sufficiently accurate?
- Are the databases maintained/fully constructed? Is further research/input required to improve the design of the databases?

Comments

- During the 2001 outbreak, delays occurred in entering data from the field into databases.
- There were also difficulties linking samples from farms. Modern IT needs to be employed throughout the whole system (e.g. bar coding of samples) to resolve this problem.
- An aggregated data storage system, which is kept up to date, is required. This system needs to be put in place now. People should become familiar with the system, so that they are prepared in the event of subsequent outbreaks.
- DEFRA are already undertaking the major task of coordinating their databases.

- It would be beneficial to develop a unified database including local knowledge from the whole of the UK.
- The difficulties associated with obtaining accurate information of on farm location were mentioned and the further development of a GIS component would be very useful.
- It was considered that there are now opportunities to collect much better data and thought needs to be given to the improvements that are needed.

2A. What models are needed?

General Comments

- It was generally agreed that models are very useful tools and can serve a range of purposes.
- During the 2001 outbreak benefits were obtained from using a number of models.
- Models can be used to predict the scale of an epidemic, but predictions of the tail end can be unreliable.
- We need to identify what output is required from models. The questions asked need to be specific, and not broad-based such as 'what do we do?'.
 - Modellers need to identify what data are required to develop the models to answer the specific questions. Different modelling groups may require different data.
- In the future it would be useful to have a family of models which interact. The family should include:
 - *strategic models* - to examine potential control strategies
 - *tactical models* - to assist in decision making during an outbreak
 - *operational models* - to assess whether control strategies are feasible (economically/logistically)
 - *training models* - to consider various scenarios
- Models can also be used to identify areas that require further research.
- Development of these models should be proactive rather than reactive.

Specific Comments on Types of Models

- *Models to identify the risk of invasion of disease*
 - This would be difficult.
- *Models to predict the potential spread of disease, given the situation under which a particular outbreak may occur*
 - The Interspread Simulation Model can be used to model the potential spread of the virus during an epizootic.

- *Models to determine the impact of different control strategies on limiting the spread/incidence of disease*
 - Models can be used to quantitatively assess the impact of different control strategies.
 - Although the culling strategy is effective, models can be used to assess whether other strategies would be better.
 - In particular, modelling of vaccination campaigns and their consequences would be useful.
 - Modelling allows novel methods of control to be explored prior to any future outbreaks.
- *Models to determine the economic consequences of differing control strategies, given the situation under which a particular outbreak may occur*
 - Models used during the 2001 outbreak highlighted the need for a huge input of resources.
 - Identifying the economic and logistical requirements of control strategies would be useful for assessing whether strategies are actually feasible in the field.
 - Cost-benefit analyses of different control strategies would be valuable.
 - The economic and welfare consequences associated with restricting animal movements need to be assessed.
 - Social impacts of control strategies should also be considered.
- *Are the Interspread Simulation Model and air dispersion models sufficient? What further developments are needed?*
 - With regards to Interspread, it is better to keep it parsimonious, rather than further increasing its complexity.
 - At present the air dispersion models do not produce reliable predictions for the dispersal of FMDV over long distances. More data on the characteristics of plumes and the minimum dose required for infection of different livestock species are required. Models also need to be validated.

Specific Comments on Future Research

- *What immediate research or development is required to ensure that epidemiological models are more reliable should another outbreak of a highly infectious exotic disease occur in the near future?*
 - Various factors (e.g. movement of animals) may influence the epidemiology of a range of exotic animal diseases. Consequently, these factors could be used in models other than those just for FMD.
 - However, current data on movement of animals are not sufficient. Census data incorporating seasonal trends are required (e.g. census data from June will not necessarily be the same as data from February).

- It needs to be established how accurate data must be in order for models to produce reliable predictions.
- Modellers should indicate what data they require (e.g. quantitative data on virus transmission, the role of the carrier state etc.).

2B. Application of models

Questions

- Could the models that were developed during the 2001 FMD outbreak be quickly and easily adapted to future outbreaks of FMD or other exotic diseases of livestock in the UK?
- Is it worth developing epidemiological models any further before critical information on aspects of disease transmission and questions relating to the use of vaccines have been answered by experimental studies?
- Who will be able to use the models once developed, and to what audience is their use targeted?

Comments

- We are still a long way from having even basic models that could be applied to other exotic diseases that threaten the UK. In particular, vector-borne diseases are much more complex to model.
- There is a need for research in order to learn more about transmission parameters. Models will never be entirely accurate while certain aspects, such as the risk associated with carrier animals, remains unknown.
- Models can be used centrally to inform decision-making.
- Models can also be used (across a range of levels) for training purposes.

3. Analysis

Questions

- Has the 2001 FMD outbreak been sufficiently analysed? What are the anticipated/finalised results?
- What more could be gained by further detailed analysis of the data from the 2001 FMD outbreak?
- Could analysis of data be improved? How would this be done?
- Has the analysis of data from various models given a true picture of infectious status/spread of FMD and/or other diseases?

Comments

- There was general agreement that a thorough analysis of the 2001 outbreak is essential.
- A lot of effort has been put into producing a valid dataset from the 2001 outbreak. Analysis of the 1967-68 dataset provided a lot of information and it is likely that the same will apply for the 2001 dataset.
- It would be useful to look in detail at the pattern of animal movements in the country at the time.

4. Economics

Questions

- From an economic point of view, can models accurately predict the most cost effective control methods and can these models incorporate sociological factors that may affect the acceptance and success of different approaches?
- Should support for theoretical aspects of modelling be funded by sources other than DEFRA? If so, what other funding bodies would give support?

Comments

- Incorporating economic and sociological impacts of different control into models would be valuable.
- DEFRA has a lot to gain, in terms of controlling future outbreaks, from funding work into modelling. However, much of the work on developing FMD models and models of other diseases has been funded from other sources.
- DEFRA should support the development of new models. Previous FMD models are based on models for human diseases and consequently include spatial mixing. However, mixing does not occur to the same extent in animal diseases due to restrictions on animal movement.
- DEFRA will consider funding work in this area. An assessment of how best to assign limited funds between modelling and experimental work is required.
- It was also noted that responsibility for animal health does not solely fall to DEFRA and other parties and funders have interests in this area.

5. Expertise

Questions

- Could DEFRA buy in modelling expertise if and when required or should in-house expertise be developed?
- If research and development is put out to university groups, how can DEFRA be assured that models and the expertise required to run the models will be available when and if a new outbreak occurs?

Comments

- DEFRA should investigate a range of options including buying in expertise, developing in-house expertise and collaborating with the EU.
- Interdisciplinary teams should be formed so that modellers are working alongside vets and others who have a thorough understanding of the farming industry and the field situation.

6. Collaboration

Questions

- Is there sufficient collaboration between veterinary and medical research groups with expertise in disease modelling?
- Is there sufficient collaboration and co-operation between mathematical modellers and those working to control disease outbreaks as efficiently as possible?

Comments

- The remark was made that this was the first meeting for which modellers and vets involved in the field control of FMD had been brought together for discussions. Prior to this DEFRA staff, field vets and field epidemiologists had been working flat out to control the FMD outbreak.
- It was generally agreed that closer links among modellers, epidemiologists, veterinarians etc. need to be established. These links need to be created now, prior to any future epizootics.
- An improved mechanism of communication needs to be put in place. Suggestions included:
 - organising workshops
 - organising a programme of visits among research groups
 - setting up focus groups concerned with databases and modelling
- In addition, international collaborations should be pursued. Outbreaks in the UK are rare and so researchers should try to gain experience of FMD in other parts of the world. Experience of both epizootic and enzootic situations would be valuable.

CONCLUSIONS

- The value of models is recognised, but there is a need for further development and improvement.

- It would be beneficial to develop a range of models that interact with each other. These models could be used for:
 - exploring the effectiveness of potential control strategies (strategic)
 - identifying the most effective control strategy during an outbreak (tactical)
 - identifying whether a particular strategy is economically and logistically feasible
 - cost-benefit analyses of control strategies
 - assessing the social impacts of control strategies
 - training

- Work on developing and integrating databases, and verifying data records from the outbreak must continue.

- A mechanism of improved communication among experts needs to be put in place. Further development of models related to control strategies must involve collaboration between modellers, FMD experts and those with field experience of disease control approaches and in depth knowledge of livestock farming.

Recommendations

This meeting has provided useful information and ideas. The next stage will be to focus on more specific issues and questions relating to different types of models and areas where development is most needed. It is proposed that this is done through more focused workshops and meetings aimed at determining clear research requirements.

Subjects proposed for further work include:

- detailed analyses of data from the 2001 outbreak and use of this data in the modelling of alternative control strategies
- improvement and expansion of current models such as Interspread and air dispersion models
- further development of other models for the spread of FMD, taking forward work started during 2001 outbreak

Support for research in this area is dependent on the availability of funds. The present DEFRA research budget for exotic diseases is fully committed, but bids have been made for extra funding.