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Quantitative risk assessment case study: smuggled meats as disease vectors

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Summary
Outbreaks of foot and mouth disease (FMD), African swine fever (ASF), classical swine fever (CSF) and swine vesicular disease (SVD) can cause significant economic and social costs and severe trade limitations. A number of commodities may be contaminated with these hazards, including meat and meat products derived from infected animals. Great Britain (GB) enforces a number of regulations to prevent the importation of such pathogens. However, the illegal importation of meat provides a route by which controls may be circumvented and pathogens imported. This paper discusses a series of risk assessments examining the disease risk to the GB livestock population of FMD, CSF, ASF and SVD from the illegal importation of any meat product from any region in the world. This paper describes the development of a quantitative risk assessment model designed to identify the major contributors to this risk, and discusses the challenges posed when undertaking such complex risk assessments.

Keywords
African swine fever – Classical swine fever – Disease control – Foot and mouth disease – Import – Meat smuggling – Quantitative risk assessment – Swine vesicular disease.

Introduction

The project described here was initiated, in early 2002, at the highest level of government when the Secretary of State for Environment, Food and Rural Affairs chaired a meeting of all the major stakeholders and the risk assessment team. This expressed a commitment to incorporating risk assessment into decision making involving all interested parties. The aim of this paper is to describe the process and discuss some lessons learned.

In 2001 Great Britain (GB) suffered an outbreak of foot and mouth disease (FMD), suspected of being initiated by the smuggling of meat or meat products contaminated with FMD virus (FMDV) which subsequently found their way into incompletely treated pig swill. This led to strong political pressure for action to control meat imports. In response to the recommendations of the Royal Society Inquiry into Infectious Diseases in Livestock (16), and political pressure to provide evidence of the risk, in 2002 and 2003 the Department for Environment, Food and Rural Affairs (Defra) commissioned a series of quantitative risk assessments. These were to assess the risk of infection of GB livestock by FMDV, classical swine fever virus (CSFV), African swine fever virus (ASFV) and swine vesicular disease virus (SVDV) due to smuggled meat and meat products. Their findings were to assist in deciding what future disease prevention and control policies would best suit the specific circumstances of GB. The country has a considerable global trade, and vast numbers of people pass through key airports and ports. Thus, not only disease control issues but also wider practical and business issues must be considered when determining disease control policies.

The risk assessments were undertaken using the guidelines given in the World Organisation for Animal Health (OIE) *Terrestrial Animal Health Code* (22), and are described in detail in two risk assessment reports produced by the Veterinary Laboratories Agency (VLA) and published by Defra (19, 20). It was clear from the outset that the methodology had to reflect the many origins of meat contaminated by the specified hazards, and the diverse routes by which it is imported illegally into GB, and then distributed such that livestock can be exposed and infected.

Methods

In estimating the risk associated with the importation of illegal meat, a common model structure was used to develop the risk assessment for each virus. The model parameters were specified for each of the viral hazards as appropriate, reflecting the differences in the microbiological characteristics of each of the four hazards. The risk assessment model consists of three separate components:

a) estimating the flow of illegally imported meat into GB

b) estimating the probability that meat is contaminated with a virus, specifically FMDV, ASFV, CSFV, and SVDV

c) identifying exposure pathways and estimating the probability and frequency of infection in GB livestock caused by contaminated meat.

Together these components, which are summarised in Figure 1, represent the various pathways by which the virus is transferred from its country of origin to livestock in GB.

To give maximum information to policy makers, a modelling approach was required which would allow for traceability of all significant parameters at each stage of the process. The model was therefore constructed using an object-oriented code, which also permitted examination of the behaviour of the model at each step. The modelling structure also reflects the various possible routes taken by contaminated meat. Hence, the model is complex in terms of the level of detail given by the model results, the mathematical formulation, and the volume of information and data that was collated to populate the model. The following presents a summary overview of some of the key components of the model. Full technical details are published elsewhere (9, 20).

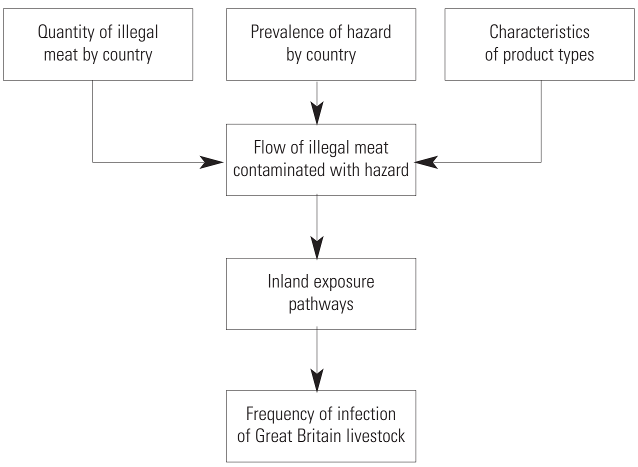

Fig. 1
Summary of the components of the risk assessment to estimate the frequency of infection of livestock following exposure to illegally imported meat

Estimating the quantity of meat imported illegally into Great Britain

The primary source of data used to derive the flow of illegal meat for this assessment was the illegal animal product seizures (ILAPS) database. This database was set up at the Ministry of Agriculture, Fisheries and Food (now a part of Defra) in April 2001. Until April 2003, it recorded seizure information provided both by enforcement agencies and by other supporting agencies. These agencies included the Association of Port Health Authorities, Local Authorities Co-ordinators and Regulatory Services, the State Veterinary Service and the Food Standards Agency (FSA). Until April 2003 Her Majesty's Customs and Excise (now part of Her Majesty's Revenue and Customs [HMRC]) supported the work of these agencies in various ways, including making seizures in the public interest, but was not itself a legal enforcement agency. However from that date, when it obtained legal enforcement powers, seizure data was entered directly into a database set up by HMRC, and data for April to September 2003 was taken from that database. The seizures reported included those from all countries which were, at the time, outside the European Union (EU), and thus included those which became Member States in 2004.

The ILAPS database holds data on seizures of products of animal origin (POAO) where the importers sought to evade correct importation procedures. Information was gathered on smuggled products in freight (both air and sea), mail, and passenger baggage. Data were also collected where smuggled products were seized inland from trading premises. Data for entry onto ILAPS were collected on meat (including poultry meat), fish, dairy products and other goods, for example honey.

Once a seizure was made, the seizure data were submitted by the agency concerned to the Illegal Imports Team within the International Animal Health Division of Defra, for entry to the ILAPS system. Ideally, these data should have comprised:

– weight of the products seized

– point of origin

– mode of transport
– point of entry to the UK
– the enforcement agency which made the seizure
– details of the importer and the exporter.

However, the database had a number of limitations. There were problems in obtaining a unified approach to the data submitted due to the multitude of reporting authorities. Some agencies provided more details than others. In addition, as the process of reporting became more embedded, the frequency of reports increased. Thus the data collected in the later months are more likely to give an accurate picture of meat flows by type, origin, etc. Both the risk assessment team and Defra were aware of these limitations. However, even though ILAPS did not contain complete details of 100% of the seizures made, it represented the best dataset available at the time on the level of seizures of illegal meat and meat products.

The data recorded on ILAPS made possible the categorisation of the types of meat flows from the different regions in terms of the meat species and product type. Although seizure data can be taken as indicative of the properties of the flow of illegal products from each region, assessment of the quantity is more complex. The data in ILAPS only recorded information about seizures. At that time the system did not hold information about the frequency of searches where no seizures occurred. In addition, searches were not conducted on a random basis but ad hoc, and targeted towards those routes (primarily air passenger traffic from certain regions) where it was known that there was a significant flow of POAO. It was therefore necessary to develop 'scale factors' which related the total quantity of illegal meat seized to the probable total flow of successfully smuggled illegal meat.

To obtain scale factors for each mode of entry of illegal meat (that is: sea freight containers, passenger baggage, post plus courier, and air freight), data collected in another exercise commissioned by Defra were analysed. In this exercise, a number of additional checks were carried out at major air and seaports, in an attempt to identify the proportion of smuggled meat missed in existing routine enforcement checks. It focused on the two modes of entry considered to be of most significance: passenger baggage and containerised sea freight. Data from this exercise supplemented the routine data available in the ILAPS database. This information provided a basis for deriving scale factors for passenger baggage and sea freight, updated to decrease bias as improved ILAPS data became available, and formatted as distributions to take into account the uncertainty inherent in the data source. This additional study significantly enhanced capacities to use information in the database to estimate the flow of illegal meat, and highlights the importance of continuing communication between the risk assessment team and the risk managers. Communicating difficulties about key data gaps enabled the initiation of further work to help address those data gaps.

In summary, the stages in generating a representative flow of meat for the model are:

a) the assumption was made that the seized consignments from a given region, as reported in the ILAPS database, are representative of the number and type of illegal meat imports from that region (but not necessarily the weight). (It was recognised that this assumption may not always be true, but no additional information was in existence.) The difference between the total estimated number of illegal imports and the number seized at ports was calculated by using the scale factors;

b) each of the product type descriptions in the ILAPS database (approximately 1,725 different words or phrases because the information was collected in free format) was translated into generic descriptions of meat species and processes, using categorisations such as cattle, pig, sheep, and cooked, dried, bone-in and de-boned to describe the meat species and product types respectively;

c) the four main transport modes for meat into GB (that is sea freight, air passenger baggage, air freight and post) were used to characterise the mode of arrival into GB from each region;

d) the estimated proportion of the meat flow seized from each region, by mode of entry, was derived from the scale factors. This was expressed as a matrix, allowing the numbers of importations for each region and transport mode to be assessed separately, thus maintaining a high degree of detail in the model and therefore in the final estimates of risk;

e) the weight of meat imported in each consignment was derived by sampling from a weight distribution obtained by statistical analysis of the ILAPS data; these weight distributions are a function of the mode of arrival.

The resulting estimates of the amount of illegal meat imported were on average 11,875 tonnes of meat per year, with a 90% certainty interval ranging from 4,398 to 28,626 tonnes per year. This estimate is based on seizure data available at the time of risk assessment development: specifically, the 29 months up to 30 September 2003.

Prevalence of hazard

For each region of the world the prevalence of each of the hazards was required to enable an estimate of the proportion of the flow that would be contaminated. A major problem highlighted through the development of these risk assessments was the shortage of data about the disease status of many of the individual territories considered. Due to the way that trade can spread diseases when pathogens are present, the global disease situation is monitored, and data collected, by a number of organisations. The main source of such information is the OIE. Each year the OIE collates information on the disease status of member countries for a number of diseases, recording the number of establishments affected by each disease that have been reported throughout the year. However, the OIE members comprise only 73% of the countries considered in this study. There is no centralised source of disease-occurrence data for non-member countries. As each member country initiates its own reporting of disease occurrence, some countries may fail to, or be unable to, report complete data. Some countries do not report at all. Reports of disease occurrence are likely to be underestimates, as some establishments that are affected may go unnoticed or not be reported to the appropriate authority within the country.

Other bodies are also involved in collating data on outbreaks, though none are as extensive as the OIE database. The World Reference Laboratories and United States Department of Agriculture Animal Health Manual, and the Food and Agricultural Organization's (FAO) Emergency Prevention System (EMPRES) bulletins and alerts provide relatively independent data (1, 4, 18). However, these data are qualitative and not available for all years. The European Commission for the Control of FMD provides yearly updates on disease situation and control measures for FMD but is limited to selected countries (5). For some minor trading nations, particularly island communities, there are no available data on previous outbreaks, although import and export partners can be identified. To address this key data deficiency, all available data were aggregated to provide estimates of prevalence, as summarised in Figure 2. The evidence base(s) for each component of Figure 2 is given in Table I. Initially this system was intended to model illegal meat flows by country of origin. However the data available were unable to support this level of differentiation. Therefore, to reduce the reliance on country-level data with their associated high degrees of uncertainty, estimates were aggregated on a regional basis. The final estimates of risk were therefore less dependent on poor-quality, country-specific data.

Product characteristics

To estimate the levels of viral contamination, viral loads in the tissues of infected animals were estimated from published data; for example for FMD the following references were used: pigs (2, 12, 13), sheep (17), cattle (3, 8). Survival data on the persistence of each of the hazards were then incorporated into the model to determine how well, and for how long, the virus will persist in the product during processing and subsequently. Incorporation of this

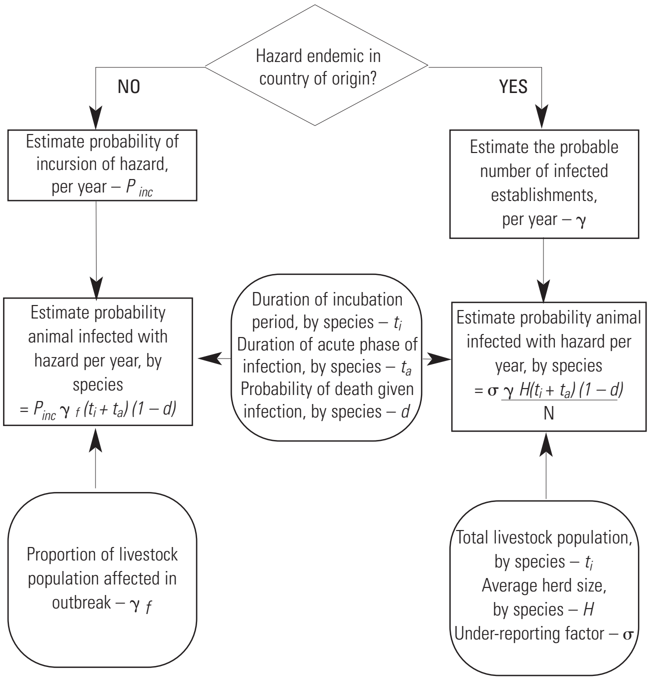

Fig. 2
Summary of the stages to estimate the prevalence of each hazard in the 223 populated territories considered in the risk assessment

information provides an additional level of distinction between product types; for example CSFV has been reported to survive in smoked meat for up to 90 days (15), while in salted meat there is evidence of survival for up to 313 days (11). Accumulating these data with processing times and transportation times from the region of origin to GB made it possible to estimate the degree of degradation in the viral contamination level which occurs during production and transit. This allows an estimation of the contamination level of the product at the point of import into GB. The expected flows of meat into GB contaminated with each of the hazards is summarised in Table II.

Inland exposure pathways

The final component of the model describes the mechanisms by which the imported meat reaches livestock, plus an estimate of the dose of pathogen (the hazard) to which animals would be exposed. This was achieved through the development of a module which describes all the pathways by which each hazard may reach livestock. These pathways include swill feeding, landfill of meat waste from restaurants, and other methods of disposal such as littering. The module includes the pathways that appear on scientific grounds to be the most significant, taking into account the microbiological characteristics of each of the hazards and the impact of each of the mechanisms and processes upon the virus. The pathways modelled for FMD are shown in Figure 3. Full

Table I
Evidence used to estimate the prevalence of each hazard in the territories considered in the risk assessment

Parameter description		Value	Source of data (reference)
Probability meat is contaminated			
Number of affected establishments		–	OIE (21), AVIS (1), USDA (18), EMPRES (4), EUFMD (5), expert opinion (19, 20)
Level of underreporting		40%	Expert opinion (19, 20)
Livestock population size		–	FAOSTAT (6)
Period of viable virus in tissues			
Total duration of infection	ASF	230 days	(10, 14)
	CSF	19 days	(10, 14)
	SVD	12-21 days	(10, 14)
Latent period	FMD-cattle	1-7 days	(10, 14)
	FMD-swine	2-8 days	(10, 14)
	FMD-sheep	3-12 days	(10, 14)
Acute period	FMD-cattle, sheep	4-11 days	(10, 14)
	FMD-swine	6-7 days	(10, 14)
Probability of death	ASF	0.05-1	(10, 14)
	CSF	0.95-1	(10, 14)
	SVD	0	(10, 14)
	FMD-cattle, swine, sheep	0.02-0.2	(10, 14)
Probability of selecting an infected non-farmed species		10% lower than farmed	Expert opinion (19, 20)
Proportion of population affected in an outbreak	ASF	Triangular (0, 0.0022, 0.022)	OIE (21)
	CSF	Triangular (0, 0.0005, 0.005)	OIE (21)
	SVD	Triangular (0, 0.0004, 0.004)	OIE (21)
	FMD	Triangular (0, 0.002, 0.02)	OIE (21)

ASF : African swine fever
AVIS : Advanced Veterinary Information System
CSF : classical swine fever
EMPRES : Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases of the FAO
EUFMD : European Commission for the Control of Foot-and-mouth Disease
FAOSTAT: Food and Agriculture Organization statistical databases
FMD : foot and mouth disease
OIE : World Organisation for Animal Health
SVD : swine vesicular disease
USDA : United States Department of Agriculture

details of the pathways for each hazard and evidence upon which the pathways were selected are provided in the VLA risk assessment (20). The absence of earlier studies meant that many of the parameters relied on expert opinion. Given the level of exposure (dose) for livestock, the probability of infection was estimated using published dose–response information; for example for FMD the model of French *et al*. (7) was adopted. Aggregating these probabilities over the entire flow of illegal imports provided an estimate of the frequency of infection per year for each hazard.

Frequency of infection of Great Britain livestock

Table II
Estimated flows of the quantity of illegally imported meat that is contaminated with each of the hazards per year into Great Britain

Hazard	Contaminated flow per year (kg) 5th percentile	Mean	95th percentile
African swine fever	0.007	0.046	0.138
Classical swine fever	7.5	263	794
Swine vesicular disease	0.002	0.007	0.021
Foot and mouth disease	64.6	214.2	565

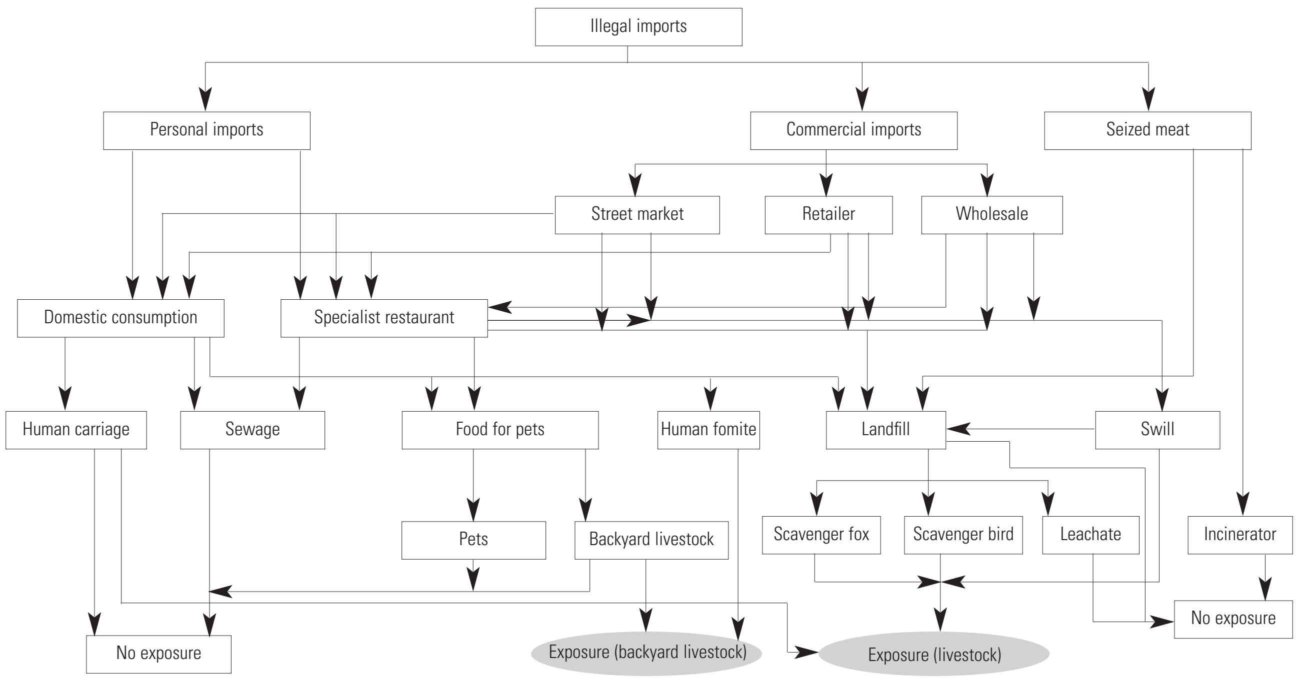

Fig. 3
The inland exposure pathways for foot and mouth disease (FMD) describing the plausible routes by which FMD virus might reach livestock from illegally imported meat

The frequency of infection is a result of the flow of contaminated meat through the inland exposure pathways which results in the exposure of livestock to each viral hazard considered. The risk assessment provides a numerical estimate of the risk posed by each region of the world for each disease considered. The frequency of infection per year for each hazard is summarised in Table III.

Model validation

Validation of risk assessment models cannot generally be undertaken by comparing outputs with known values. The known values (by definition) do not exist at the time, and many years – possibly hundreds or more – may be needed to verify the model for low probability estimates, even though these may be of high impact and thus of crucial importance to the risk manager. Thus risk assessment best practice requires that such models are validated by peer review, using appropriate biological and – for quantitative models – mathematical experts. This process is designed to ensure that the data used are the best currently available, all assumptions are reasonable, and the mathematical computations are correct. This peer review process was undertaken for the model used in this assessment. Biological and other relevant experts were consulted on input data and risk pathways throughout the process. Preliminary results were also subject to inspection by relevant experts, which was followed by model review and adjustment where appropriate. An independent peer review of the overall mathematical model was undertaken when development of the model was complete.

Table III
The frequency of infection per year for infection with each of the hazards as a result of the illegal importation of meat and meat products into Great Britain

Hazard	Frequency of infection per year		
	5th percentile	Mean	95th percentile
African swine fever	2.9×10^{-5}	6.1×10^{-4}	2.3×10^{-3}
Classical swine fever	0.006	0.3	0.8
Swine vesicular disease	3.4×10^{-10}	6.9×10^{-10}	2.2×10^{-8}
Foot and mouth disease	0.0017	0.015	0.053

Factors contributing to the risk of infection

Investigation of the factors that contribute to the risk of infection will further inform our understanding of the risk to livestock from the importation of illegal meat, aiding decision makers when considering control policy. The risk of infection can be considered in a number of informative ways: for example, by region, by product type or by exposure pathway. Some of the key insights gained from this work are summarised.

Risk of infection by region based upon mean estimates

For full definitions of the regions, and the uncertainty distributions surrounding the mean estimates, see VLA, 2004 (20).

– Imports from the Near and Middle East were the most likely to cause infection with FMD, with imports from this region accounting for approximately 47% of the frequency of infection;

– imports from Eastern Africa represent the greatest proportion of the risk of infection with ASF, with imports from this region accounting for approximately 96% of the frequency of infection;

– imports from Western Africa represent the greatest proportion of the risk of infection with CSF, with these imports accounting for approximately 79% of the frequency of infection;

– imports from Eastern Europe represent the greatest proportion of the risk of infection with SVD, with imports from this region accounting for approximately 70% of the frequency of infection. Some of the countries in this region are now within the EU, and thus no longer have individual import controls.

Product type based upon mean estimates

For full definitions of the uncertainty distributions surrounding the mean estimates, see VLA, 2004 (20).

– Imports of cattle and pig meat represent the greatest proportion of the risk of infection with FMD, accounting for approximately 88% of the total frequency of infection. Cattle were the dominant species, accounting for approximately 64% of the total risk of infection. A large proportion of the risk was attributed to exposure to FMDV-contaminated bone-in and dried de-boned meat, with imports of such products accounting for approximately 69% of the total frequency of infection;

– imports of de-boned meat are the most likely to cause infection with ASF. Imports of such products account for approximately 77% of the total frequency of infection;

– imports of dried de-boned meat are the most likely to cause infection with CSF. Imports of such products account for approximately 70% of the total frequency of infection;

– imports of ground meat (in matrix) represent the greatest proportion of the risk of infection with SVD. Imports of such products account for approximately 52% of the total frequency of infection. De-boned meat is the next largest contributor with 22% of the total frequency of infection.

Import and inland routes

– The model considers the importation of meat by various routes of entry. These are passenger baggage, air freight, sea freight and post, plus couriers. The model results indicated that passenger baggage was the biggest contributor to the risk for each of the disease hazards. However, the large quantities involved often suggested a commercial incentive, rather than importation for private use;

– of all the possible pathways considered by which livestock could be exposed to contaminated meat, meat that follows the human carriage route contributes the most to the risk of infection. Here individuals may inappropriately dispose of leftover meat, for example by littering, direct feeding or ‘fly-tipping’ (illegal dumping of rubbish, often on the verges or in ditches along country lanes). Illegal swill feeding was the second largest contributor to the risk (all swill feeding to pigs is now illegal in GB), and scavengers at landfill sites the third. However, based on mean estimates, these last two routes account for a very small proportion of the total risk. The feeding of backyard livestock and wild boar make minor contributions to the estimate of risk;

– once the meat has passed through all the stages considered by the model and results in livestock exposure, for FMD it was found most likely that infection would occur in pigs. Of the predicted risk of FMD infection per year, on average 96% of the risk was associated with commercially reared pigs, 3% with cattle, 1% with sheep and goats, and a low risk in backyard pigs and wild boar.

Discussion

The development of the risk assessments posed a number of challenges to both the risk managers and the risk assessment team, including:

a) managing the complexity of the required information about seizures. This was collected by a number of organisations, making collaboration between organisations essential;

b) appropriately involving stakeholders in the risk assessment process, thus ensuring they are informed and have the opportunity to contribute as the process develops, and that they have realistic expectations of the insights that risk assessments can and cannot provide;

c) handling the development of risk assessments which are fit for purpose – in this instance with a very large scope and many intermediary results – while under pressure for a quick completion due to the urgency of the issue;

d) communicating the use of the results and the importance of outputs from the risk assessment, in addition to the estimates of risk.

Below we discuss these key issues further.

The importance of cross-organisational collaboration and partnership

This risk assessment utilised many types of data from many different sources. Some of the data – for example those used to estimate the prevalence of FMD in each region of the world, or to estimate the level of virus present in different meat products, or for dose–response modelling – relied heavily upon routinely reported outbreak data, literature searches and individual biological experts. However for other data, for example those needed to estimate the probable quantity of illegally imported meat, or to identify probable post-import exposure pathways, there was no 'routine' source of information. New approaches were necessary involving extensive collaboration across different interest groups.

Taking the quantity of illegal imports as an example, there were two major sources of data. The first was the ILAPS database, a cross-organisational information-gathering exercise set up in 2001 and run by Defra to record the seizures of illegally imported meat, as identified primarily by local and port health authorities (PHA). This required the active involvement and support of several organisations. The ILAPS database contained the hard data which provided the starting point on which the estimates of quantities of illegal imports were based. Despite the imperfections of the database, it played an essential role as an underpinning basis for estimates of illegal imports and without it, it is hard to see how such an estimate could have been made. The second major source of information for this model input was HMRC and PHA officers themselves. They were willing to set aside time to discuss with the risk assessment team the methods, problems, successes and failures in the checking procedures at points of entry to GB. These discussions helped put the ILAPS data into context and allowed the quantified estimation of illegal imports. Without this essential cross-organisational cooperation, primarily between Defra and HMRC but including other organisations, it is very difficult to see how this quantification could have been attempted.

The value of stakeholder involvement

Throughout the process, there was close stakeholder involvement in the form of a steering group set up and chaired by Defra. The steering group had representatives from a wide range of organisations, including the National Farmers' Union (NFU), FSA, HMRC, local authorities, commercial transport providers, restaurant organisations and others, and met regularly throughout the risk assessment process. The meetings provided a very useful forum for the exchange of information and ideas; questions, disagreements and points of view were all aired and technical explanations given. The format for involving stakeholders developed as experience was gained, and in such a way as to maximise efficiency and reduce time diverted from the risk assessment itself. The most effective format was found to be a brief presentation of progress, with handouts supplied and time for debate, at meetings held only whenever there was truly something new to discuss. One particular issue which caused concern was that of the presentation of intermediate results. Some of the audience were unaware that risk model development is an iterative process, and for this reason intermediate outputs are no guide to the final result. However, we were asked by Defra to provide these intermediate outputs, and this caused temporary difficulties for some participants.

The steering group forum enabled the risk assessment process and results to gain public support from a wide range of stakeholders, which is vital in such a high profile undertaking. Nevertheless this process is time consuming, and for urgent projects it must be recognised that it does delay the output.

Interpretation, uncertainty and the value of results

Quantitative risk assessments, by definition, produce a result in numerical terms. Developments in stochastic methodology and the utilisation of expert opinion have resulted in numerical outputs which incorporate and describe the uncertainty in the system. This raises a number of issues with regard to the interpretation, meaning and use of those outputs.

When risks have to be managed and decisions made, it is understandable that the more certain the facts, the easier it is to make decisions and plan policy. Thus, in general, risk managers would like uncertainty minimised. A single number output from a quantitative risk assessment is therefore easier to deal with and understand. One typical initial response, when the 5th to 95th percentile range of a distribution is very large (as in this case), is that 'it doesn't really help'. However, this totally understandable reaction ignores the most important feature of the result: namely that there are very large uncertainties, and they do need to be taken into account when making decisions. A deterministic model which gave as a result a single number might have been easier to understand, but it would almost certainly have been wrong – and where the uncertainties are very great, it could be very badly wrong. Using mathematics does not make uncertainty go away. The risk manager who wants to make best use of a risk distribution needs to understand exactly what that distribution is telling them, which is much more than a single number ever could.

But the final result from a risk assessment, and in particular a complex quantitative assessment such as this, is unlikely to be the most important feature of that assessment. The basis of any good risk assessment is the identification of the 'risk pathway', the chain(s) of events necessary for the unwanted outcome to occur. The delineation of this risk pathway itself will almost always provide insights, which will assist the risk manager in managing the final risk.

In this risk assessment, for example, identifying all the possible inland exposure pathways, and considering which were plausible and which were not, was of great value, and could be used again for assessments of other exotic pathogens with similar characteristics. The specific methodology used here also allowed for the estimation of a vast number of intermediate outputs, for example the quantity of illegally imported meat by region of origin, the quantity of contaminated meat by type of product, and many others. Again this provides insights into the problem and indications of where risk reduction measures might most successfully be employed. These are all outputs which would have been impossible without the formal methodology of a risk assessment, and for the intermediate estimates, a quantitative risk assessment of the type employed. Such insights are, in the authors' opinion, at least as valuable as the final numerical result, and probably more so.

The risk manager is not the only person interested in the results, however. The FMD epidemic, for example, was a particularly sensitive and politically charged issue, and in its aftermath there were many interested parties. The difficulty of presenting uncertainty to an audience not used to dealing with probabilities meant that the clarity of presentation of the results was crucial if they were to be understood. Although a 'single number' output would have been simpler to present, it would have been particularly misleading given the uncertainties in the data. Of course, even when the uncertainties are explained, it is very easy for those with other agendas to quote only, for example, the mean values, thus distorting the results and allowing misinterpretation.

Fit for purpose: how complex must a model be?

Risk assessments may range from something very brief, rapid and simple, which would usually be qualitative, to something very complex which takes considerable time and resources, and which may be qualitative or quantitative. The choice between simple or complex will depend upon various factors, but one will be the speed with which an initial answer is required. Where an output is required within a day, there is little choice in the approach. However, in a situation such as the one described in this paper, the initial request for a risk assessment derived from an outbreak which had already occurred. Although speed of response was identified as a factor, a quantitative risk assessment was specified by the risk managers concerned. Thus, the need for a trade-off between speed and precision was present from the start. The question therefore arises, would a simpler, speedier model have been preferable? And if so, how could that have been achieved?

The advantages of the complex methodology actually used were that it was able to provide a great range of answers, and multiple insights into the pathways involved. In addition, simplification may have made model adaptation to other diseases much more complicated. In this model, so many factors were explicitly considered that the adjustments to the model necessary for use with other pathogens were very clear, specific, and data based – and thus relatively simple. A simpler model (for example using some kind of black-boxing to replace explicit parts of the risk pathway) would only have been able to deliver a final 'result' with few variant arguments or scenarios.

It is difficult in any event to see how a useful but much simpler quantitative model could have been developed which covered all the risk pathways. The model used grew out of a consideration of the risk under investigation – which included potentially contaminated animal products of a huge variety of types, with different properties and from all regions of the world, reaching GB through a number of routes, then passing through a wide variety of inland exposure pathways to all susceptible livestock species. Indeed, because of this, the assessment broke new ground in microbial and animal health risk assessment with respect to the scope (whole world, any product, any route…) and mathematical structure of the model.

One apparent possibility for simplification might have been to select a specific product from a specific country, and look at the probability of that causing infection in GB. But – unless this procedure were repeated for all products from all countries individually, and gave some assessment of comparable quantities by each route – this would not have answered the questions about which were the riskiest regions, or products or exposure pathways. And so we arrive full circle back at the need for a model of the type and complexity used, if we wish to answer the questions posed. Such a model takes time to build, and resources to provide the data inputs – but once built can be re-used and adapted as new data becomes available, or for other pathogens. Of course, incorporation of newly available data or model adaptation for other pathogens require model validation of equivalent rigour to that described for initial use.

Was this large and complex project worth the resources used?

The intention of the risk assessment was to provide information to help guide strategies for reducing the specified risks in the future. To this end, insights were provided which can be summarised as follows:

– illegal importation of meat contaminated with the hazards specified is a plausible contributor to the risk of an outbreak occurring in GB

– the types of meat products, and the regions from which they originate, which make the largest contribution to the risk were identified

– a number of preconceptions about the possible origins and pathways of infection were examined and discounted

– the main modes by which contaminated meat arrives in GB were identified

– potential exposure pathways were elucidated

– the major data gaps which prevent the reduction of uncertainty in the results were identified.

These insights have been useful in a number of ways. Information on the patterns of flow of illegal meat into GB has subsequently been incorporated into policy and practice to help inform enforcement activity by HMRC, for example in targeting checks on passenger baggage.

The risk assessment highlighted the problems inherent in having a number of authorities responsible for border security, in terms both of enforcement and of data gathering. There has been a huge increase in enforcement at the border since HMRC took over responsibility for anti-smuggling activity against illegal imports in April 2003, reflected by a massive increase in seizures of POAO since that time, as shown in Table IV.

Table IV
Number of seizures of products of animal origin by year from 1 April 2001 to 31 March 2005

Period	Number of seizures
1 April 2001 – 31 March 2002	2,053
1 April 2002 – 31 March 2003	7,819
1 April 2003 – 31 March 2004	15,838
1 April 2004 – 31 March 2005	25,610

As with any quantitative model, the specific results reflect the data inputs. Changing conditions will lead to changes in the data, and once available this can be incorporated into the model. For example, new data on seizures or on the current global disease situation could be incorporated relatively easily to give an updated assessment if required. In fact, following on from the identification of the key data gaps, and to put the risk from illegal imports into the overall GB risk context, a further related project is now being undertaken: a qualitative risk assessment looking at legal and illegal imports of animals and animal products, from both within and outside the EU. New data identified in this may in due course be appropriate for updating the quantitative model. As has been stressed, due to the high level of uncertainty, the results obtained must be interpreted with caution. More complete quantitative data would begin to reduce this uncertainty, and targeted studies are the only way to obtain this and thus get maximum benefit from the model.

In summary, a number of demonstrated benefits have resulted from this work, but to maximise use of the modelling method developed requires data not yet available. Perhaps the model is a methodological development which is ahead of its time.

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Étude de cas sur l'évaluation quantitative des risques : les viandes importées illégalement en tant que vecteurs de maladies

M. Wooldridge, E. Hartnett, A. Cox & M. Seaman

Résumé

Les foyers de fièvre aphteuse, de peste porcine africaine, de peste porcine classique et de maladie vésiculeuse du porc peuvent engendrer d'importants coûts économiques et sociaux et de graves limitations aux échanges. Un certain nombre de marchandises sont susceptibles d'être contaminées par les agents de ces maladies, notamment les viandes et les produits carnés tirés d'animaux infectés. La Grande-Bretagne a mis en œuvre diverses réglementations visant à empêcher l'importation de ces agents pathogènes. Néanmoins, l'importation illégale de viandes représente un moyen de se soustraire aux contrôles et par là même un risque que des agents pathogènes soient importés. Le présent article examine une série d'évaluations du risque de fièvre aphteuse, de peste porcine classique, de peste porcine africaine et de maladie vésiculeuse du porc auquel est exposé le cheptel britannique par suite de l'importation illégale de tout type de produit carné en provenance de n'importe quelle région du monde. L'article décrit l'élaboration d'un modèle d'évaluation quantitative du risque visant à identifier les principaux facteurs de ce risque et passe en revue les problèmes posés par la réalisation de ces évaluations complexes.

Mots-clés

Contrôle des maladies – Évaluation quantitative du risque – Fièvre aphteuse – Importation – Importation illégale de viandes – Maladie vésiculeuse du porc – Peste porcine africaine – Peste porcine classique.

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Ejemplo de evaluación cuantitativa del riesgo: la carne de contrabando como vector de enfermedades

M. Wooldridge, E. Hartnett, A. Cox & M. Seaman

Resumen

Los brotes de fiebre aftosa, peste porcina africana, peste porcina clásica y enfermedad vesicular porcina pueden inducir importantes pérdidas económicas y problemas sociales y acarrear estrictas limitaciones al comercio. Muchos artículos pueden resultar contaminados, en particular la carne y los derivados cárnicos procedentes de animales infectados. En Gran Bretaña están en vigor una serie de reglamentos para impedir que esos patógenos penetren en el país. Sin embargo, la importación ilegal de carne es una práctica inasequible a los controles, y por ello una posible vía de importación de patógenos. Los autores describen una serie de procesos para determinar el riesgo de que la población de ganado británico contraiga una de las cuatro enfermedades citadas a resultas de la importación ilegal de cualquier producto cárnico de cualquier región del mundo. También exponen la elaboración de un modelo de determinación cuantitativa del riesgo, concebido para identificar los principales factores que contribuyen a ese riesgo, y examinan las dificultades que se plantean al llevar a cabo evaluaciones de semejante complejidad.

Palabras clave
Contrabando de carne – Control de enfermedades – Determinación cuantitativa del riesgo – Enfermedad vesicular porcina – Fiebre aftosa – Importación – Peste porcina africana – Peste porcina clásica.

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