Global change: impact, management, risk approach and health measures – the case of Europe

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Summary
Global changes, including an increase in trade and global warming, which act on the environment, are likely to impact on the evolution of pathogens and hence of diseases. To anticipate the risks created by this new situation, a French group of experts has developed a method for prioritising animal health risks. This is a two-phase method: the first step is to identify the diseases whose incidence or geographical distribution could be affected by the changes taking place, and the second step is to evaluate the risk of each of these diseases.

As a result of this process, six priority diseases were selected: bluetongue, Rift Valley fever, West Nile fever, visceral leishmaniasis, leptospirosis and African horse sickness.

The main recommendations were: to develop epidemiological surveillance, to increase knowledge of epidemiological cycles, to develop research into these diseases and to pool cross-border efforts to control them.

Keywords
Climate change – Europe – Risk prioritisation – Transmissible animal disease.

Introduction
Global climate change in the form of global warming now seems an undisputed fact. The latest report of France’s National Observatory on the Effects of Global Warming (ONERC) provides an excellent summary (9).

The majority of scientists have also recently accepted that human activity has contributed to global warming (+4). There nevertheless remain many uncertainties concerning the speed of global warming, its duration and scope, each type of activity’s share of responsibility for it (54) and the role and importance of warming compared with other global changes (such as the movement of goods and people between continents and changes in livestock practices), which also disrupt ecosystems (56). All this makes it likely that such changes will have a wide variety of impacts on the Earth’s various natural habitats (37, 52). Since this may affect the parameters of many epidemiological cycles, one of the underlying questions is whether it is possible to anticipate changes in risk levels. This is a source of concern for many countries’ health services and may have a range of impacts on animal health (economic costs) and public health.
This article proposes a possible approach, applied to the specific context of France following the heat wave in summer 2003 (4).

Background to the study

Although this special edition of the Review discusses many aspects of global climate change, the current study focuses on a few specific points. One of the first tasks was to ascertain whether the selected geographical area (a Western European country with a surface area of around 550,000 km²) was of the right scale to provide answers. Discussions with climatologists and meteorologists confirmed that it was. Climate change may differ between northern and southern France: for example, the Mediterranean rim could become more arid, whilst the north of the country could become wetter than it is today, and the south-west could see sharp temperature rises (48).

As a result, the vegetation would change over time. Projections by the French National Institute for Agronomic Research (INRA) in Nancy show what could happen to forest cover in France during the 21st Century (Fig. 1). This gives an idea of the potential impact on fauna (both vertebrate and invertebrate), reservoirs and vectors. Many epidemiological cycles could be affected.

We need to add another parameter, the human factor of increased trade, the impact of which extends far beyond the movement of goods and people across the face of the Earth. For commercial and other reasons, current transport systems have the ability to transfer any potential pathogen anywhere in the world in a matter of hours. If the conditions are favourable in the place where the pathogen has been transported (for example following a change in climate), the pathogen could trigger a public health, animal health or plant health problem. The difference in climate between tropical and temperate zones used to provide a safety barrier that served to limit the release of pathogens to a few rapidly controlled cases. This could well change. While the pace of pathogen releases could remain constant, the likelihood of imported diseases gaining a foothold could increase. It is therefore problematic to make a comparative analysis between conducive factors stemming from the climate alone and those associated with human activities.

New diseases could be introduced, or the incidence or geographical distribution of existing diseases could alter. The most pessimistic scenario is one in which new diseases are introduced, coupled with an increase in the incidence and geographical distribution of existing diseases.

The following data illustrates the method used to analyse and interpret the associated risks, bearing in mind the inherent limitations of this type of exercise.

Risk prioritisation method

Against this background, following the heat wave that struck France during the summer of 2003, France’s health and agriculture ministries commissioned the French Food Safety Agency (AFSSA) to submit a scientific opinion identifying the various animal diseases, particularly zoonoses, which could affect France’s territory in the coming years under a global warming scenario. The brief also stipulated that these diseases should be evaluated for their potential risks to public health and the livestock industry.

An AFSSA multidisciplinary working group was set up to address these complex issues. The working group was headed by F. Rodhain (Institut Pasteur) and included E. Albina (French Agricultural Research Centre for International Development [CIRAD]), G. André-Fontaine (National Veterinary School of Nantes), M. Armengaud (French Academy of Medicine), G. Dreyfuss (Faculty of Pharmacy, Limoges), B. Dulour (National Veterinary School of Allot), G. Duvallet (University of Montpellier), F. Moutou (AFSSA-Lerpaz) and S. Zientara (AFSSA-Lerpaz). The group, composed of entomologists, bacteriologists, virologists, parasitologists and medical and veterinary epidemiologists met regularly over a one-year period (7).

The working group selected a two-phase method:
– identification of diseases whose incidence or geographical distribution could be affected by global warming
– evaluation of the risk for each of these diseases.

Identification of diseases whose evolution is climate-influenced

The first requirement was to identify the animal diseases (transmissible to humans or otherwise) which global warming could cause to emerge on French territory or, if they were already present, cause to develop further (increased incidence and/or geographical spread).

A long list of diseases was examined, based on the World Organisation for Animal Health (OIE) list of notifiable diseases and supplemented by proposals from the experts in the group.

The group of experts began by endeavouring to ascertain whether climate could influence the development of these diseases. A key parameter, in the context of climate change, is the elements in the disease cycle enabling the pathogen to circulate either in the environment or in a host, vector or reservoir.
Four major types of risk were identified:
- risks associated with arthropod vectors
- risks associated with molluscs
- risks associated with wild vertebrates
- other risks (in particular those arising from climate-related changes in human behaviour).

To make a first selection of the diseases that might evolve in response to global warming, all the diseases in the long list were examined for their mode of transmission in order to exclude them from the above-mentioned four categories of risk or to classify them in one of the categories. During this initial classification, a whole range of diseases unrelated to the above-mentioned four risks were rejected (i.e. diseases with no clear link to climate). This allowed diseases with reservoirs mainly comprising domestic species and direct transmission to be rapidly eliminated (such as foot and mouth disease in France).

Around forty diseases were selected and classified into one of the four risk categories.

A more in-depth analysis was then made of each of these diseases.

The analysis was based on bibliographic data. A short monograph on each disease was drawn up on the basis of

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**Fig. 1**

Maps covering French forestation, today (upper left) and projection for 2050 (upper right) and 2100 (bottom)

Geographical distribution of seven chorological groups by discriminant analysis. The extension of evergreen oak (group 8) on the one hand, and the regression of beech (group 4) on the other, are spectacular

*Source: http://www.nancy.inra.fr/extranet/com/carbofor/groupes-climat.htm*
a predefined plan. First, the susceptible species were identified, then the mode of transmission, and finally the epidemiological status in France and the rest of the world. Table I gives a list of bibliographic references that were studied as part of the scientific analysis to select the six priority diseases.

After this description of each disease, the group of experts identified and estimated qualitatively the risks and possible evolution factors associated with global warming.

A qualitative estimation of evolution potential was made using the AFSSA qualitative risk evaluation matrix, which has been refined over time (3, 5, 6, 22, 23), as well as the five qualitative assessments shown in Table II.

This analysis led the group of experts to eliminate a number of other diseases whose development would not, in its opinion, be influenced by global warming (zero risk).

At the end of the initial selection stage, twenty diseases were selected as liable to develop in response to global warming (Table III).

### Risk evaluation

Since risk is a combination of the likelihood of occurrence of a harmful event and the consequences of the event (55), it was necessary to estimate the likely impact of the evolution of the diseases.

Three types of impact were identified for each of the twenty diseases selected at the end of stage one:

- the health impact for the animal (average seriousness for the animal)
- the impact of zoonoses on public health (prevalence and average seriousness)
- the collective economic impact for animals.

Once again, the description and analysis of the impact were based on the bibliography and the qualitative evaluation was discussed jointly within the expert group. The group used the same qualitative assessments (23) as for evaluating the likelihood of evolution of the disease.

The results of this evaluation can be seen in Table III.

After determining all the impacts of the twenty diseases that were deemed likely to be influenced by climate, the group of experts also considered the likelihood of disease evolution and the level of impact, ultimately identifying six priority risk diseases for which action needed to be taken:

- bluetongue
- Rift Valley fever

### Results

The French experience highlighted the fact that animal diseases that were likely to evolve in response to global warming were diseases that have a contamination mode closely linked with the natural environment and, consequently, whose transmission components (reservoirs and/or vectors) are likely to be modified by global warming.

Although the selection was based on a fairly long list of highly diverse diseases, at the end of the above-mentioned process, five of the six diseases selected were found to be vector-borne diseases. This clearly indicates the importance of global warming on vector development, as predicted by certain epidemiological models (42, 49).
Many of these diseases, which had disappeared from temperate zones, could re-emerge or spread there.

In France, West Nile fever re-emerged in the south of the country in 2000, even though no episodes had been detected in the country since the 1960s (58).

Similarly, bluetongue emerged in the Mediterranean basin at the end of the 1990s (40, 59); several serotypes (4, 11, 17, 45) then spread rapidly. The vector responsible throughout the Mediterranean basin was Culicoides imicola.

This vector had been carefully monitored and, thanks to regular trapping, its emergence and establishment in southern France were spotted (11, 17, 27), which made it possible to assess the increased risk of bluetongue occurrence in continental France (45). In August 2006, to general surprise, bluetongue suddenly emerged in northern Europe (51, 53), although C. imicola had never before been trapped in these regions, which are normally too northerly for this vector. The obvious conclusion (which then had to be proven) was that the bluetongue virus had probably been transmitted by one or more other vectors (e.g. Culicoides obsoletus, C. dewulfi or others). Although already suspected, this has not yet been definitively demonstrated (8).

**Discussion of methodology**

The method used to select a small number of diseases deemed to be a priority risk in a global warming context has advantages as well as limitations:

– The main advantage of the method is that it makes it relatively easy to select a small number of diseases from a long list. The simplicity of the method makes it easy to communicate to others and it is therefore accessible to everyone, especially risk managers. This simplicity results in experts focusing their discussion on the scientific data rather than on the method itself.

– The main limitation is the subjectivity of the qualitative evaluation. The assignment of diseases to one of the five categories is necessarily subjective to some extent, as it is influenced by the personality of the individual experts. Pooling bibliographic information and following up with a group discussion reduces such subjectivity without, however, eliminating it altogether.

– Another limitation is that it is difficult for the group to decide on one of the five possible categories. However, this problem is alleviated by comparing the different diseases. The qualitative assessment for each disease was therefore not ‘absolute’ but ‘relative’.

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### Table III

Qualitative estimation of the impact of diseases with a non-zero likelihood of evolving in response to global warming

<table>
<thead>
<tr>
<th>Diseases whose evolution is climate-influenced</th>
<th>Impact on human health</th>
<th>Impact on animal health</th>
<th>Economic impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equine infectious anaemia</td>
<td>Zero</td>
<td>Low</td>
<td>Negligible</td>
</tr>
<tr>
<td>Babesiosis and theileriosis</td>
<td>Negligible</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Botulism</td>
<td>Low to moderate</td>
<td>Low to moderate</td>
<td>Negligible to low</td>
</tr>
<tr>
<td>Cercarial dermatitis</td>
<td>Negligible</td>
<td>Zero</td>
<td>Zero</td>
</tr>
<tr>
<td>Dirofilariosis</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
</tr>
<tr>
<td>Distomatosis</td>
<td>Negligible to low</td>
<td>Negligible to low</td>
<td>Negligible</td>
</tr>
<tr>
<td>Ehrlichiosis and anaplasmosis</td>
<td>Negligible</td>
<td>Low</td>
<td>Negligible to low</td>
</tr>
<tr>
<td>Mediterranean boutonneuse fever</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Zero</td>
</tr>
<tr>
<td>Bluetongue</td>
<td>Zero</td>
<td>Moderate</td>
<td>Moderate to high</td>
</tr>
<tr>
<td>Anthrax</td>
<td>Negligible</td>
<td>Negligible to low</td>
<td>Negligible</td>
</tr>
<tr>
<td>Rift Valley fever</td>
<td>Moderate</td>
<td>Moderate to high</td>
<td>Moderate to high</td>
</tr>
<tr>
<td>West Nile fever</td>
<td>Low to moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Q fever</td>
<td>Low to moderate</td>
<td>Low</td>
<td>Low to high</td>
</tr>
<tr>
<td>Visceral leishmaniasis</td>
<td>Negligible to low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Leptospirosis</td>
<td>Moderate</td>
<td>Low to moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Diseases caused by cyanobacteria</td>
<td>Zero</td>
<td>Negligible</td>
<td>Negligible</td>
</tr>
<tr>
<td>Screwworm</td>
<td>Negligible</td>
<td>Low to moderate</td>
<td>Negligible</td>
</tr>
<tr>
<td>African horse sickness</td>
<td>Zero</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Psittacosis</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
</tr>
<tr>
<td>Other rickettsial infections</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Zero</td>
</tr>
</tbody>
</table>
Overall, the selection method was easy to use and, in the absence of other tools, it enabled the experts to achieve the stated objectives.

Recommendations and prospects

Upon completion of the AFSSA risk prioritisation process, the experts made a series of recommendations (7). They recommended specific surveillance and control measures for the six diseases deemed to be a priority risk. These measures are described in Table IV. Some of the expert group’s general recommendations could be implemented internationally, whilst some more specific recommendations could also be implemented at European level.

Disease risk prioritisation

The list of diseases selected by the AFSSA expert group is specific to the situation in France and cannot be transposed directly elsewhere. However, the expert group’s proposed method could be used, perhaps with adaptations, by other countries wishing to conduct a similar risk prioritisation exercise.

Disease risk prioritisation is important because it can be used to introduce measures tailored to each disease, in particular specific surveillance measures that cannot be recommended for too large a number of diseases because they are too cumbersome and costly.

Establishment and development of epidemiological surveillance

Surveillance for the emergence and/or spread (when the disease is already present on the territory) of the diseases identified as of high risk from global warming is seen as a vital element.

Specific surveillance methods must be defined for each of the priority-risk diseases, according to their biological and epidemiological characteristics.

These methods could be based on:
- epidemiological monitoring (regular collection and analysis of the epidemiological information available from literature, information networks and experts)
- ecological monitoring (surveillance of wild vectors and reservoirs to highlight any demographic or geographic variations)
- economic monitoring to track the emergence of new markets, the opening of new trade channels, trade volumes and types of trade
- epidemiological monitoring or early warning systems based on the early detection of clinical signs of the animal disease
- more traditional epidemiological surveillance systems for the diseases already present on the territory in question.

Setting up and developing such surveillance and monitoring systems require information and training for field operators (farmers and veterinarians), which must be stepped up, especially for diseases that are currently exotic to the territories concerned.

Table IV

Special recommendations made in April 2005 by the group of experts from the French Food Safety Agency (AFSSA) for the surveillance and control of the six priority diseases identified in France

<table>
<thead>
<tr>
<th>Disease</th>
<th>Working group recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluetongue</td>
<td>Definition of an emergency plan combining clinical serological and entomological surveillance with control measures (slaughter and/or vaccination depending on the epidemiological status). Creation of a vaccine bank</td>
</tr>
<tr>
<td>Rift Valley fever</td>
<td>Alert system to detect an abnormal increase in abortions amongst ruminants in southern France during the summer, and definition of a response plan</td>
</tr>
<tr>
<td>West Nile fever</td>
<td>Reinforcement of clinical surveillance of equidae and monitoring of mortalities amongst wild birds and animals by the French game mortality surveillance network (SAGIR)</td>
</tr>
<tr>
<td>Visceral leishmaniasis</td>
<td>Entomological surveys coupled with the identification of strains in enzootic zones</td>
</tr>
<tr>
<td>Leptospiroses</td>
<td>Epidemiological surveys on the role of species likely to be involved in transmission and contamination of the environment. Appointment of a veterinary reference laboratory for the collection, identification and monitoring of strains</td>
</tr>
<tr>
<td>African horse sickness</td>
<td>Entomological surveillance of C. imicola</td>
</tr>
</tbody>
</table>
It is also vital, especially for monitoring networks, to build laboratory diagnostic capabilities in consultation with the international reference centres for these diseases.

Finally, epidemiological surveillance can only be truly useful and effective if it can be made cross-border in nature whenever the need arises. It is therefore seen as essential for countries in the same geographical region to harmonise their methods and results independently of any commercial interest. The recent example of bluetongue in northern Europe is a perfect illustration of this need. The disease emerged in August 2006 in the region of Maastricht, in a geographic zone close to three different countries (the Netherlands, Belgium and Germany) and rapidly spread to five countries (51).

**Expanding knowledge of epidemiological cycles**

As mentioned above, the priority diseases influenced by global warming are those where the main transmission mode is closely linked with nature. Vector-borne diseases are therefore of particular concern, as are diseases where the main reservoir is wild.

The epidemiological cycles of these diseases are often only partially understood, especially since they tend to vary from one geographic zone to another. The epidemiological cycle of Rift Valley fever in East Africa differs significantly from that in West Africa (20). In addition, the methods of release and possible persistence of the bluetongue virus in northern Europe have still not been identified (51).

We therefore need to expand our knowledge of the biocology of the hosts and vectors of these diseases. Knowledge of vectors and vertebrate reservoirs is all too often sketchy. Not all the factors influencing population dynamics in response to climate change are known as yet. However, climate change determines ecological and epidemiological contacts between wild and domestic populations, as well as with humans.

Similarly, it is vital to gain a better understanding of the influence of abiotic factors (temperature and humidity) on the development of vectors. In addition, the vector competence of species liable to play an epidemiological role in the transmission of certain high-risk diseases is not always properly measured, and the factors governing vectorial capacity need to be studied in greater depth.

This type of vector study calls for skills in medical entomology. However, in many developed countries, such skills have been deemed less useful in recent decades and have not always been adequately maintained or updated.

Finally, epidemiological models should be developed because they are valuable for predicting the emergence of these diseases, which often have complex cycles. These models could become important decision-making tools, provided that they are supplied with reliable data from the field.

**Development of various avenues of research**

Research into diagnostic and screening tools could be intensified, chiefly to provide field laboratories with the tools to perform preliminary identifications using modern methods. This type of research would benefit everyone and would therefore warrant establishing a network of international partner laboratories.

In European countries, the systems currently used to control exotic diseases are based mainly on monitoring animal movements and on detecting and destroying infected animals. These methods are cumbersome and costly, are often inadequate and would be difficult to implement for diseases that might become established in Europe for long periods. Furthermore, the principle of vaccinating certain animals has been adopted for vector-borne diseases that have already been present in southern Europe for several years (such as bluetongue), against which vector control has proven largely ineffective. Given the risk of vector-borne diseases spreading throughout Europe, it is necessary to develop research into effective vaccines that can be used to implement strategies for differentiating infected from vaccinated animals (DIVA).

The creation of effective, well-tolerated vaccines with zero environmental impact that provide a real means for vector control should also be made an applied-research priority.

Finally, in terms of research, it is seen as essential to use human science to gain a better understanding of human attitudes and behaviour. This could be used to guide the analysis of behaviour-related risks and to make the communication of appropriate prevention messages more effective.

**Harmonising cross-border control methods**

The effort to control most of the diseases whose development could be influenced by global warming should not remain a strictly national exercise. Such diseases will attempt to spread, as the example of bluetongue in southern and northern Europe has shown. Vector-borne diseases, more so than other infectious or parasitic diseases, know no boundaries. It is therefore essential for the control of vector-borne diseases to be cross-border in nature, and for there to be exchanges and consultation among control officials in the different...
countries concerned. This need emerged very clearly during the bluetongue serotype 8 epizootic (51) which has already affected five northern European countries (Germany, Belgium, France, Luxembourg and the Netherlands).

Conclusion

At the end of this study, six diseases were singled out for France: four viral, one bacterial and one parasitic. Four are zoonoses and two are strictly animal diseases. Five are vector-borne diseases (some of which are notifiable) and the sixth is water-borne. While this report highlights the heavy influence of climate change on modes of transmission, it remains difficult to distinguish between the direct impact of climate change and the evolution related to or concomitant with human behaviour.

Leishmaniasis is moving northwards and some specialists have even predicted its emergence in Great Britain in the near future. There are several reasons for concern: the vectors are moving northwards; changes in the landscape as a result of town planning and agriculture are conducive to the vector; and populations of wild and domestic ducks are growing. Moreover, these various trends can occur simultaneously.

In the case of leptospirosis, warmer weather encourages more bathing but reduces water points, resulting in closer proximity between wild fauna and bathers.

A final point is the decision to exclude tick-borne diseases from this study while including insect-borne diseases. In its discussions, the working group was unable to reach a decision on how ticks would react, or are already reacting, to climate change. Indeed, different tick species will probably react differently.

The exclusion of tick-borne diseases means that, although this study was able to provide a response at a given moment in time, it may be appropriate to develop an ecology watch body to continually monitor the evolution of the ecological parameters of many epidemiological cycles in order to anticipate future risk variations as effectively as possible.

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References


