Expert views on European research needs regarding emerging infectious animal diseases: results of a Delphi study

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Summary

Background
Emerging infectious animal diseases can have a significant international impact on social economic and environmental level, of which prevention and control measures should be prepared at national as well as at international level. However, research to support such policy development is mostly carried out at national level, which may lead to duplication of research effort. Dedicated trans-national research programmes, coordination and cooperation could lead to more effective research efforts. Yet such cooperation is still in its infancy. Therefore, the EMIDA consortium tries to establish effective research collaboration and develop a common Strategic Research Agenda. To develop such an agenda it is essential that a cross-European consultation process is installed. This can only be achieved by incorporating multidisciplinary expertise across the whole EU into foresight activities.

Objective
To systematically consult experts, through a foresight exercise, in the area of emerging infectious animal diseases about current and future European capacity in the identification, mitigation and prevention of infectious animal diseases (in particular in relation to production animals), and to identify what steps are required in order to develop a common research agenda of utility at a pan-European level.

Methods
A two round Delphi study was conducted to explore the views of experts on issues relating to emerging infectious animal diseases of livestock in Europe.

Main results
A list of drivers was identified that may influence the incidence of emerging infectious animal diseases in both the short and medium term. Drivers related to regulatory measures and natural science developments were thought to decrease the incidence, and socio-economic factors to increase the incidence of emerging infectious animal diseases. From the first round a list of threats to animal health was compiled and participants combined these threats with relevant drivers to help focus further research and identify possible solutions to mitigate these threats (for definitions see page 11). Participants emphasised that socio-economic research is needed to understand drivers of emerging infectious animal diseases, as well as to develop measures which are both socio- economic and technical. In order to achieve this, resources are needed to fund these scientific advances. Furthermore, the results have been used as input for discussions at a pan-European consensus workshop, which aimed at achieving clearly identified agreements and disagreements on the research topics to include in the common Strategic Research Agenda.

Conclusion
This study has shown that on the one hand research that focuses on natural scientific drivers is key to controlling emerging infectious animal diseases. However, participants have emphasised that socio-economic insights are needed to understand relevant factors that influence emerging infectious animal diseases. From this it can be concluded that interdisciplinary research combining both natural and social research themes is required. Some of the European research budget needs to be allocated so that effective prevention and mitigation strategies can be developed.

Acknowledgements

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Introduction

Infectious animal diseases have the potential to have negative social, economic and environmental impacts internationally. Climatic, biophysical and anthropogenic factors influence contact rates between hosts, pathogens, vectors and their reservoirs, ultimately shifting the (animal) disease burden on regional level (de La Rocque et al., 2008). The spread of infectious animal diseases is driven by many factors, for example, translocation of people and their livestock, (increased) contact between wild animals, domestic animals and people. Modern farming practices may act as an "amplifier" of emerging infectious animal diseases. Modern trade activities, and transport mechanisms and routes served to sometimes expedite the spread of disease.

Prevention of, and response to, emerging animal diseases relies heavily on science, as research makes a significant contribution to the development of new disease prevention and control policy tools and their translation into concrete risk management measures. Although the legislation that underpins policy for the control of diseases is determined at the EU level, the research that supports policy development and implementation is primarily carried out at the national level. At the present time, this is largely uncoordinated between member states. Lack of coordination across Europe can potentially result in duplication of effort in some areas, and insufficient research infrastructure in other areas (see for example, Hugas et al., 2009; McMurray D.N., 2001).

The aims of EMIDA are as follows. To increase transnational cooperation and coordination of research programmes on animal health through providing research founder network structures and organise common research programmes. The development of a common strategic research agenda is a tool to help to organise jointly funded programmes[1].

To develop the common strategic research agenda (SRA), a combined approach will be adopted, which will incorporate foresight exercises. The SRA will be developed based upon the following four parts: foresight review, Delphi study, pan-European stakeholders consensus workshop, and other sources (such as: governmental documents). For a schematic overview see Figure 1.

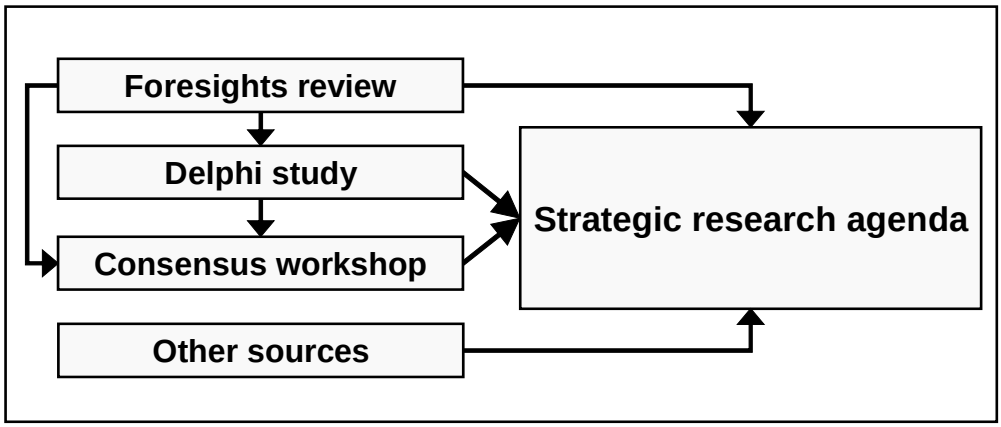

Figure 1. Positioning of the Delphi study within the development of the strategic research agenda by EMIDA Foresight and Programming Unit (FPU).

[1] More information can be found at www.emida-era.net/.

The Delphi study described in this report has been developed from a literature study and two small workshops. The literature overview of foresight studies in the animal health area was compiled by members of the EMIDA Foresight & Programming Unit. The results of the Delphi study will not only be used to develop the SRA. They have also formed the basis of discussions at a pan-European consensus workshop.

Regional differences exist for emergence of animal infectious diseases in Europe. This depends on, for instance, pathogen occurrence and reservoirs, host-pathogen interaction, husbandry systems when considering production animals, and vector occurrence and competence when considering vector borne diseases. In addition, animal movement, mainly due to international trade and transport, is an important cause for the spread of infectious animal diseases (Fèvre et al., 2006).

As a variety of threats are introduced into previously unaffected geographical regions, differences in expert prioritisation of relevant threats, drivers or resources may occur. Regional comparisons in expert opinions regarding these issues are therefore required.

To identify Europe's regional and trans-national short and medium-term needs regarding research topics focused on preventing and mitigating animal diseases and research capacity in the animal health area, it is essential that cross-European consensus on these matters is developed. This can only be achieved if expertise across the whole EU is incorporated into foresight activities. In the current study, Delphi methodology (Linstone & Turoff, 1975) was selected as it possesses the practicability of a survey, with its benefits in terms of cost and potential access to wider expertise. The approach maintains a degree of interactivity and dialogue associated with group meetings or workshops. The use of web-based Delphi methodology is particularly useful for expert consultations of this type. Constraints associated with geographical dispersion and the number of stakeholders who can participate may be reduced with the application of survey methodologies, as many stakeholders can be approached in varied geographical locations simultaneously. Although, survey methodology, which solicits answers to key questions of interest, is ideally suited to identifying consensus and disagreement, it does not allow for any possibility of interaction between participants, or resolution of disparate opinions, which may be particularly problematic in the policy arena (Frewer et al, submitted for publication; Wentholt et al, 2009).

There is considerable variation in how Delphi surveys may be implemented. Empirical research has shown that the method (in its various forms) leads to better (e.g. more accurate) judgements and forecasts than interacting groups (Rowe & Wright, 1999, 2001). Delphi methodology has successfully been applied in the area of animal health (Van Der Fels-Klerx et al., 2002) and the evaluation of the expert perception of determinants of equine welfare (Collins et al., 2009).

The study presented here focuses on research needs and capacity building, within the remit of emerging and infectious diseases of production animals (including zoonoses) in a pan-European context. The results of the study formed the basis of discussions at a pan-European consensus workshop and were used to contribute to the development of a Strategic Research Agenda (SRA) to guide the development and implementation of co-operative research to help mitigate against such threats. The key research questions were as follows.

- Which drivers can be identified that may influence the emergence of infectious animal diseases in both the short and medium term?

- Which threats to animal health (infectious diseases) may be more likely to emerge in both the short and medium term?
- Are there gaps in the existing European capacity to prevent and mitigate emerging infectious animal diseases, if so which?
- On what specific topics regarding emerging infectious animal diseases research needs to be addressed at European level, in both the short and medium term, in order to optimise the use of European resources?

Methods

Background methodology

Delphi methodology was applied to identify research needs regarding emerging infectious animal diseases in Europe in the short term (the next 5 years), and in the medium term (the next 10-15 years). The results will be provided as an additional data stream to the EMIDA project members involved in the identification of European research priorities in the area of emerging infectious animal diseases, and will be used to develop a common EU strategic research agenda focused on animal disease identification, control and prevention in Europe. As a consequence of the European focus of the strategic research agenda, only experts within the European research area were consulted as study participants.

Design

A two round online Delphi study was conducted to explore the views of experts on issues relating to emerging infectious animal diseases of production animals in Europe (see figure 2).

Initially, two small meetings were held with EMIDA project members who reviewed relevant foresight studies on emerging animal diseases, who also represented the questionnaire development team. The aim of the first meeting was to discuss the topics to be included in the first round of the Delphi study, after which a subset of the members developed a draft questionnaire. During the second meeting, the draft questionnaire was discussed by all group members and further developed. Subsequently the questionnaire was piloted among a small group of experts, following finalisation of the first questionnaire.

The pilot was intended to trial the questionnaire using a small group of experts. This was specifically to trial the completion of the survey, and to receive feedback on the survey. The first survey was more qualitative. Participants were asked about which drivers of animal diseases, and disease threats, they expected to be important in the short term (the next 5 years) and the medium term (10 to 15 years). The second round of the survey asked questions based on the results of the first round. In addition, feedback from the first round responses was provided, primarily in terms of statistical averages.

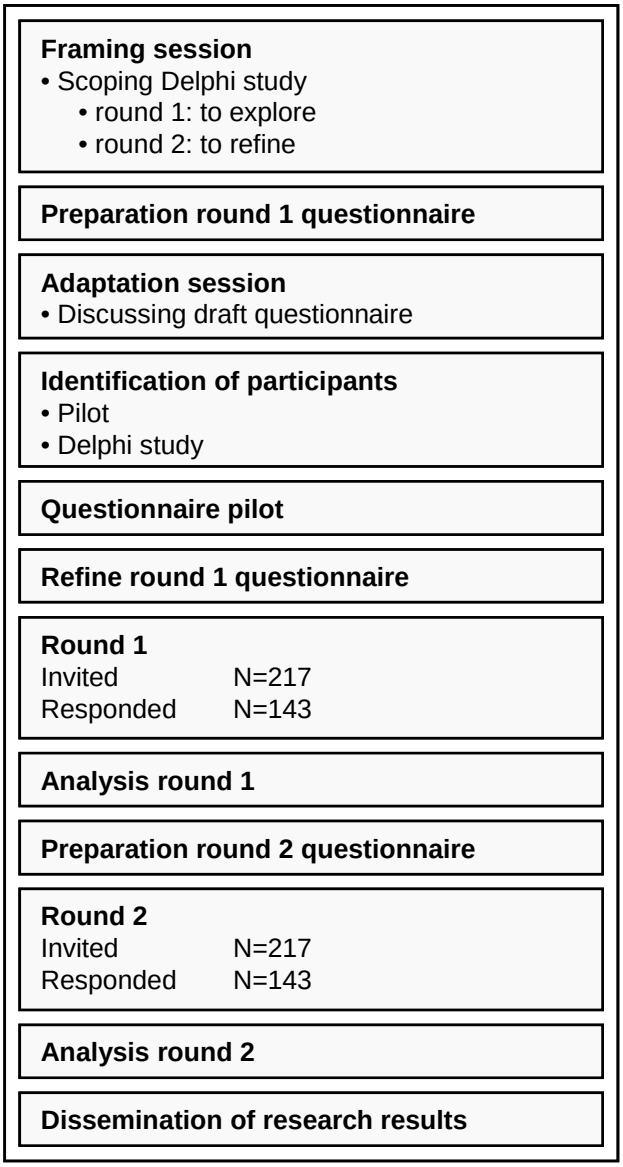

Figure 2. Study Procedure Overview.

Sample and procedure

A database of 217 relevant experts was constructed, all of whom had expertise which had been identified as being relevant by the questionnaire development team (Table 1). The review of foresight studies, as conducted by EMIDA project members, enabled identification of a range of disciplines relevant to the research questions. Participants were identified across Europe in order to solicit the opinions of all European stakeholders in the pan-European research agenda. In order to construct the database, all partners involved in the EMIDA consortium were asked to submit names of possible participants (the “cascade” approach). The database was checked to determine whether there were sufficient participants across disciplines and European member states. Where necessary (and where possible), participants from under-represented areas were added to the list of participants through requesting partners to provide additional participant names of researchers specifically with the relevant expertise.

Table 1. Overview of identified expertise domains for Delphi study.

Agro-economy
Animal diseases, zoonoses (incl. antimicrobial resistance)
Veterinary medicine
Virology
Bacteriology
Parasitology
Entomology
Epidemiology
Immunology / vaccinology
Animal genetics
Animal welfare
Communication
Criminology (incl. fraud, terrorism)
Demography
Food / feed
Ecology / nature conservation
Mathematics (incl. modelling)
Meteorology / climate
Public health
Risk assessment
Risk communication
Risk management
Sociology
Wildlife

Typically, in a Delphi study, only those participants who responded to the first round are invited to participate in subsequent rounds. The results of the second round of the Delphi survey only includes participants who had previously responded to the first round.

The Delphi study was implemented using an interactive web-site. All questionnaires were presented in English, the language used for the EMIDA-project website itself. To increase survey accessibility, participants could obtain a Word version of the questionnaire via the survey team, which could be completed off-line and returned by E-mail, fax or post to the researchers. Six participants used this alternative in the first round. Only one participant used it in the second round.

Pilot study

Participants in the pilot study were asked via E-mail invitation to respond to the survey within one week. Reminders were subsequently sent to those participants who had not responded.

Round 1

In the first round, participants were given 3½ weeks to respond to the survey. E-mail reminders were sent to participants who had not yet responded a week prior to the response deadline. Four days after the deadline had passed the database was closed. Subsequently the responses were both quantitatively and qualitatively analysed. The first round results were presented to the questionnaire development team, after which the second round questionnaire was developed.

Round 2

Invitations to the second survey were sent out to all participants who received an invitation to participate in the first round. Participants who did not return information about their background in the first round also received additional questions in this regard from the first round. As in the first round, participants were given 3½ weeks to respond to the survey, after which E-mail reminders were sent to participants who had not yet responded a week prior to the response deadline. Four days after the deadline, the online questionnaire database was closed.

Subsequently the responses were analysed using quantitative and qualitative methods as appropriate. In addition, comparisons were made between participants from different geographical regions. Participants were allocated into one of four geographical regions: Atlantic, Continental, Nordic / Baltic, and Mediterranean (European Environment Agency). This regional division reflected the assumed influence of climate zones on emerging diseases and epidemiological factors such as proximity to other areas where animal diseases were emerging.

Questionnaire content

Pilot and first round questionnaire

After introducing the EMIDA project, and the aims of the study, participants were asked to describe important forces that will be driving changes in Europe in regard to emerging animal infectious diseases. Initially questions focused on participants' opinion regarding expected general changes on the incidence of infectious animal diseases. The second set of questions focused on which threats might become important with regard to animal health, animal welfare, economic impact, food security, food safety, human health, and in terms of social impact. Subsequently, participants were asked their opinion regarding European preparedness regarding the identification, control and prevention of infectious animal diseases, and whether existing predictive methodologies were adequate. A fourth group of questions focussed on what future research topics need to be addressed at European level. Finally, some background information about the participants themselves was gathered. The first round questionnaire is provided in Annex 1.

The literature review on existing foresight studies revealed various definitions of both drivers and threats. Therefore, within the Delphi study, the use of the words 'driver' and 'threat' were defined at the beginning of the questionnaire as guidance for participants. For both definitions, participants were reminded that possible adverse human health effects need to be taken into consideration.

> *Driver: a driver or driving force is an external condition acting on a large scale (climate, energy, technology, social events, …), which has the potential to directly or indirectly influence animal and human health (in this case the (re)-emergence of infectious diseases).*
>
> *Threat: a threat is a hazard that affects directly (or indirectly) animal and / or human health, like a pathogen, pathogen-carrier or a (bio)terrorism event.*

With regard to the selected predictive methodologies, the EMIDA consortium had identified, from existing literature, a list of predictive methodologies currently used within the area of animal health[2]. From this list, four significant methodologies were selected: literature review, scenario study, horizon scanning, and workshop. These methodologies were rated in the first round questionnaire (made on five point

[2] http://www.emida-era.net/upload/pdf/Report_FPU_Foresight_reviews_final_v11_050809.pdf

scales, anchored by 1=”completely agree” to 5=”completely disagree” plus a “no opinion” category).

In the pilot study, some additional questions were included in the questionnaire as well as some additional information. All participants in the pilot study (n=13 experts) were sent an E-mail invitation, which explained their role as pilot participant and requested that they note the amount of time they had spent completing the survey. In addition to the questionnaire, participants were asked to provide feedback on: whether the questions were understandable, whether the language used in the survey was understandable, whether the questionnaire was complete with regard to topics, and whether the time periods used were appropriate. Space was also provided to allow pilot participants to make additional comments if needed.

Although the main Delphi rounds included questions both for the short and medium term, the pilot-questionaire only included medium term question for reasons of expediency as it was more focussed on the content of questions and data collection methodology.

Following the pilot study, some minor changes in wording were made, and where relevant questions were formulated to encompass both time frames.

Round 2 questionnaire

For a detailed overview of the second round questionnaire see Annex 2. Questions which had been used as “warm up” items in the first round were not repeated. For example, questions focused on the perceived driving forces that might provoke changes in general were omitted. All the major topics included in the first questionnaire were again asked in round 2 of the Delphi survey. However, in the second round, new quantitative questions were developed through identification of key issues which had emerged from coding the qualitative round 1 responses. In the first round, participants had identified key drivers of emerging infectious animal diseases in Europe. In the second round, these were coded into superordinate categories by researchers, and participants were asked to rate whether each driving force would increase or decrease the incidence of infectious animal diseases in Europe in both short and medium term (rating scale items: “increase incidence of infectious animal diseases”; “decrease incidence of infectious animal diseases”; “no effect on incidence of infectious animal diseases”; “no opinion”).

In the first round, a long list of perceived threats was obtained from the open-ended responses of round 1 participants. The list was checked in order to exclude duplications (for example, abbreviations or ‘popular’ names *versus* scientific names, like the abbreviated use of HPAI and high pathogenic avian influenza, or ‘mad cow disease’, BSE and bovine spongiform encephalopathy). This resulted in a condensed list of 34 threats. These were divided into five topic-related groups: ‘disease agents’[3]; ‘complex infections’; ‘specific animal diseases’; ‘route of transmission’; and ‘other emerging threats[4]’ (Table 2). The extent to which these threats pose an important threat to animal health was rated by participants on five point scales (anchored by 1=”very important” to 5=”very unimportant” and “no opinion”).

[3] The item was phrased in the questionnaire: “family of agents”.
[4] The item was phrased in the questionnaire: “epidemiological situation”.

Table 2. Categorised future threats to animal health from round one responses, as used in the second round questionnaire.

Disease agents
• Arboviruses • Bacterial agents • Non-zoonotic diseases • Parasites • Pestiviruses • RNA virus • Virus • Virus, endogenous • Zoonoses
Complex infections
• Complex / multifactorial disorders • Digestive system disorders • Infectious abortigenic agents • Locomotory system diseases • Mastitis • Production diseases • Reproductive disorders • Respiratory disease complexes
Specific animal diseases
• Aquaculture diseases, (fish, molluscs) • Bee diseases • Other animal diseases
Route of transmission
• Airborne infections • Direct contact zoonoses • Food borne agents • Rodent borne diseases • Vector borne diseases • Water borne agents
Other emerging threats
• Antibiotic resistance • Bioterrorism • Emerging & re-emerging agents • Emerging unknown / novel pathogens • Endemic diseases in Europe (threat of dissemination in Europe) • Increase in virulence • Opportunistic diseases • Threat of introduction exotic diseases in Europe

Following completion of these ratings, participants were asked to identify the three most important threats from all of those presented. From this, participants were then asked to link these three threats to the drivers which were also included in the second questionnaire, in order to investigate participant opinion regarding the driving forces related to the most important threats.

In round 1 of the Delphi, participants were asked to identify which research topics or research domains should be prioritised. These responses were coded and, in the second round, participants were asked to rate the extent to which they agreed or disagreed that each issue should be prioritised. Ratings were made on 5 point scales (anchored by 1=”completely agree” to 5=”completely disagree” and “no opinion”).

Participants were asked in the first round to rate the extent to which they perceived European capacity to identify, control and prevent emerging infectious animal diseases as adequate (again ratings were made on five point scales, anchored by 1=”completely agree” to 5=”completely disagree” with an additional “no opinion” category). Responses were statistically summarised (in percentages) and provided as graphical feedback in round 2. Following presentation of the round 1 results, participants were again asked whether they agreed that European capacity to identify emerging infectious animal diseases is stronger than European capacity to control them. In addition participants were asked whether they agreed that European capacity to prevent emerging infectious animal diseases is stronger than European capacity to control them. For both questions, responses were collected through the following categories: “agree”, “disagree”, or “no opinion”.

The outcomes of the Delphi study will be discussed in the next section.

Results

Sample characteristics

In the first round, 217 experts were invited to participate in the Delphi survey. Of these, 143 (66% response rate) participated in the first round of which 108 (76% response rate) participated in the second round. Participants were predominantly male (23% female in round 1 and 20% in round 2). In both rounds, most participants were over 46 years old and held more senior positions within their organisations (Table 3).

With respect to main area of expertise, participants from *animal diseases, zoonoses* and *veterinary medicine* were over-represented in comparison to the other areas of expertise. This may be a consequence of the use of personal contacts of the EMIDA network, combined with the topic of the research (Frewer et al, submitted for publication). Participants were asked at the end of the second round to provide their institutional affiliation. The complete list of institutions can be found in Annex 3.

All participants invited to take part in the first round were subsequently invited to participate in the second round. The responses of additional participants included in round 2 are not further considered in the analysis presented in this report. Participant characteristics are provided in Table 3 and Annex 4 (in greater detail).

Table 3a. Sample characteristics of Delphi study [a].

	Round 1	**Round 2**
Invited	217	143
Participated	143	108
Gender		
Female	33	30
Male	107	98
Age group		
20 – 35 years	8	7
36 – 45 years	26	20
46 – 55 years	73	56
56 – 65 years	32	25
66+ years	1	0
Relevant work experience		
< 5 years	14	10
6 – 10 years	22	20
11 – 15 years	19	18
16 – 20 years	32	25
21+ years	46	37
Region		
Atlantic	53	36
Continental	26	21
Mediterranean	27	23
Nordic/Baltic	32	27

[a] Not all participants filled in these questions.

Table 3b. Sample characteristics of Delphi study [a].

	Round 1		Round 2	
Area of expertise [b]	***M***	***A***	***M***	***A***
Agro-economy	9	9	6	7
Animal diseases, zoonoses (incl. antimicrobial resistance)	46	28	36	25
Veterinary medicine	41	29	33	21
Virology	12	24	9	20
Bacteriology	13	23	11	21
Parasitology	7	16	7	15
Entomology	7	7	7	5
Epidemiology	23	29	16	24
Immunology / vaccinology	17	20	15	18
Animal genetics	8	3	7	3
Animal welfare	10	19	9	16
Communication	3	9	3	7
Criminology (incl. fraud, terrorism)	1	2	1	2
Demography	0	2	0	2
Food / feed	3	10	2	9
Ecology / nature conservation	4	9	2	7
Mathematics (incl. modelling)	2	14	1	12
Meteorology / climate	2	5	2	4
Public health	9	27	6	24
Risk assessment	22	36	22	35
Risk communication	3	15	3	12
Risk management	14	36	14	36
Sociology	2	2	1	2
Wildlife	5	20	3	15

[a] Not all participants filled in these questions.
[b] Participants were asked to provide one main area of expertise and provide –where needed – multiple additional areas of expertise. Some participants provided multiple responses to 'main area of expertise'. (M = main area of expertise; A= additional area of expertise)

Effort was put into place to ensure participation throughout Europe. Despite this, participants from Central Europe were underrepresented (see Table 3a and Figure 3).

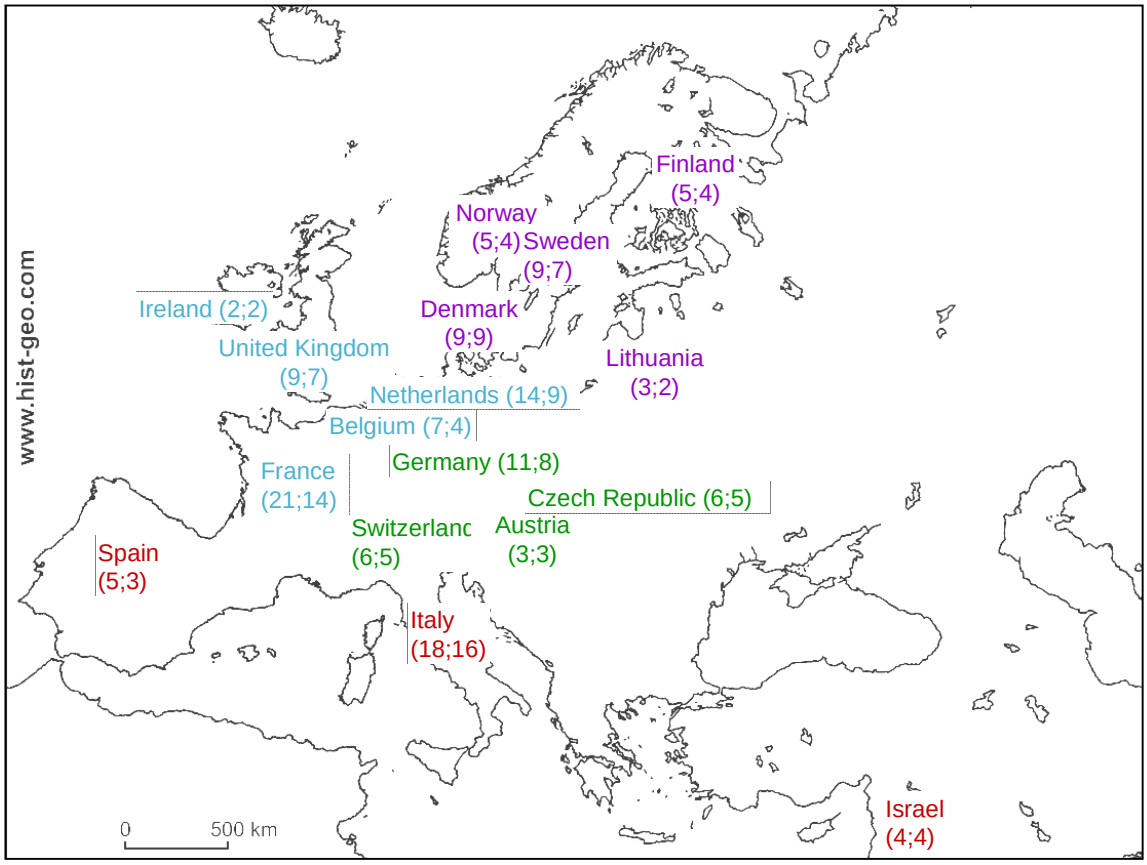

Figure 3. Graphical overview of countries where participants in both rounds of the Delphi worked (round 1; round 2). Colour coding: Atlantic, light blue; Continental, green; Nordic/Baltic, purple; Mediterranean, red.

Drivers of future threats to animal health

In the first round, participants were asked to give their opinion on future driving forces that might result in changes in infectious animal diseases within the short and medium term in Europe. Analysis of qualitative responses suggested that climate change was most frequently mentioned with regard to changes in *general* in Europe, independent of which time frame was being considered. Changes in immigration, animal welfare and food safety were thought to be of importance in the short term, whereas changes in human population growth, pathogen movement, food security and an increase in zoonotic diseases were thought to be of greater importance for the medium term.

With regard to driving forces that might result in changes in infectious animal diseases, increases in animal trade, and climate change were considered important in both the short and medium term. Climate change was linked to global warming and to emerging animal diseases such as vector-borne diseases. Additional short term issues included animal welfare related to animal production, and the need to improve animal health policy, in particular with regard to regulation. In the medium term, intensification of agricultural (in particular animal) production, expansion of the EU, increased animal movement and transmission of diseases, technology development

in the agro-domain, the development of novel vaccines, and economic influences on animal production systems were perceived to influence changes in infectious animal diseases.

Factors that might influence changes in the increased incidence of infectious animal diseases in Europe were, in the short term, developments in food trade and production systems, and the interaction of wildlife with production animals. Increased surveillance and monitoring was also identified as a relevant driver to influence the incidence of infectious animal diseases. In the medium term, factors which potentially may increase the incidence of animal diseases included expansion of the EU, and increased movement of animals and humans. The need to develop common measures, policy and programmes in the EU were also identified.

Analysis of quantitative responses resulted in a list of driving forces that may have an impact on the incidence of infectious animal diseases. Participants rated these with regard to a possible increase, decrease or no effect of the listed driving force, both in the short and medium term (see Table 4). Drivers related to regulatory and control measures (including improved risk management and novel prevention strategies) were perceived to result in potential decreases in the incidence of infectious animal diseases. Against this, increased globalisation of trade, increased transportation of animals or animal products, and increased contact between animals and between humans and animals were perceived to result in an increase the incidence of emerging infectious animal diseases.

Disagreement between the expert participants regarding the direction of impact of some drivers was also observed. These related to differentiation between international and European animal health regulations, and increased food production (Table 4).

Table 4. Effect of driving forces on the incidence of infectious animal diseases in Europe (in percentages), in the short and medium term (black: majority over 80%; dark grey: majority between 50-80%, medium grey: minority over 20%, light grey: “lack of consensus”, between 20-50% of participant responses, white: minority below 20%).

	Increase in incidence		Decrease in incidence		No effect on incidence	
	5 year	10-15 year	5 year	10-15 year	5 year	10-15 year
Increased movement of animals	97	96	1	0	2	4
Increased globalisation of trade	94	87	1	2	5	11
Increased emergence of novel infectious animal diseases	89	87	4	9	7	4
Increased interaction between wildlife and production animals	87	84	1	2	12	14
Increased trade in animal products	86	81	0	2	14	18
Climate change	77	89	0	1	23	10
EU Expansion	79	72	3	9	18	19
Increased movement of humans	74	71	0	3	26	26
Increased trade in food	63	64	0	2	37	34
Intensification of agricultural production systems	53	54	12	12	35	34
Increased European (EU) differentiation in animal health regulation	45	41	24	37	31	22
Increased food production	44	50	3	2	53	48
Increased international differentiation in animal health regulation	42	55	16	23	43	22
Increased surveillance and monitoring	17	9	71	84	12	8
European (EU) regulatory harmonisation in the area of animal health	11	5	64	76	25	19
Increased control measures, in the EU	9	9	80	83	11	9
International regulatory harmonisation in the area of animal health	8	5	71	81	21	14
Novel vaccine development	4	6	75	89	21	5
Increased control measures, outside of the EU	4	6	81	87	15	7

Future threats to animal health

In the first round of the Delphi survey, many different threats to animal health were identified, which were applicable in both the short and medium term. In addition, participants were asked to identify any infectious animal diseases that are likely to have a negative impact on each of the following impact areas in either the short or medium term: human health, food security (food availability), food safety, social impact, economic impact, and animal welfare. Slight differences were observed in the frequency of certain threats in relation to specific areas. Additional areas suggested by participants that were likely to be afflicted with a negative impact included: environmental impact, biodiversity and conservation, impact on wildlife, ecological impact, and bioterrorism.

The list of future threats to animal health identified by the first round participants, were divided into five groups according to the type of threat (see Table 2). The threats within these groups were rated in the second round in terms of their importance as future threats to animal health. All listed threats were rated 'important', though the threats within the groups Disease agents, Complex infections, and Route of transmission were regarded as being slightly more important in the short term than in the medium term (respectively, $F(1,42)=4.85$; $p=.03$ and $F(1,58)=4.99$; $p=.03$ and $F(1,71)=5.17$; $p=.03$). (See Annex 5 for complete overview of results).

Participants were then asked to select which, in their opinion, were the three most important threats from those included in the list of identified future threats (Table 5). Threats from *Other emerging threats* and *Disease agents* were most frequently selected by the participants in both the short and medium term. Though, the latter group was selected more frequently in the short term (Table 5), especially the threats 'Virus' and 'Zoonoses'. In contrast, 'Threat of introduction exotic diseases in Europe' (from *Other emerging threats*), was more frequently chosen in the medium term.

Table 5. Overview of top three most selected threats per category (values indicate frequency selected per threat).

Categorised future threats	**short term**	**medium term**
Disease agents		
Arboviruses	21	19
Zoonoses	21	15
Virus	18	13
Complex infections		
Complex / multifactorial disorders	13	15
Respiratory disease complexes	6	5
Production diseases	4	5
Specific animal diseases		
Bee diseases	4	4
Aquaculture diseases, (fish, molluscs)	1	7
Other animal diseases	0	0
Route of transmission		
Vector borne diseases	23	19
Food borne agents	9	8
Airborne infections	5	6
Other emerging threats		
Antibiotic resistance	33	27
Threat of introduction exotic diseases in Europe	23	27
Emerging & re-emerging agents	22	23

Participants were then asked to link the top three threats they had identified to the drivers which had already been included in the second questionnaire. The frequencies of threats combined to the specific drivers were calculated and ordered from high to low frequency (see Annex 6 for the complete table). Most threats were only linked a few times to drivers, and were excluded from further analysis.

Threats were selected when at least one driver was chosen 15 times or more in one or both time frames. This resulted in a list of eight threats which were most frequently connected to the drivers: *Threat of introduction of exotic diseases into Europe, Antibiotic resistance, Emerging & re-emerging agents, Zoonoses, Arbovirus, Vector borne diseases, Virus,* and *Emerging unknown / novel pathogens*[5].

For each of these eight threats relative frequencies were calculated based on the amount of participants that had selected the threat and the amount of participants that had selected the driver. Certain drivers were more frequently connected in the short term and others in the medium term.

In Figures 5a-h, the difference between these two time frames are summarised diagrammatically. Conclusions on the influence of the drivers on the threat were only drawn when more than two-third of the participants selected the driver, to create a majority outcome.

One should bear in mind that the drivers were identified with regard to having an effect on the incidence of infectious animal diseases, furthermore, that they may influence by increasing or decreasing the incidence of the threat.

From all eight threats, *zoonoses* was the only threat for which the drivers were more frequently connected to either of the time frames, in this case the medium term.

[5] Although this threat was not in the list of three most important threats per category (Table 5), this threat does meet the threshold for the current selection (see Annex 6).

Threat of introduction exotic diseases in Europe (Other emerging threats)

Delphi participants thought that the 'threat of introduction of exotic diseases into Europe' is mostly influenced by *increased surveillance and monitoring*, especially in the short term (possibly reflecting increased detection rather than incidence). Similarly, *increased control measures outside the EU* were thought to be more of influence to this threat on the short term. *Increased globalisation of trade*, *increased trade in animal products*, *increased movement of animals*, *and EU expansion*, increase the incidence both in the short and medium term. In addition, *climate change* and *increased emergence of novel infectious animal diseases* were thought to increase the incidence of exotic diseases in Europe in the medium term.

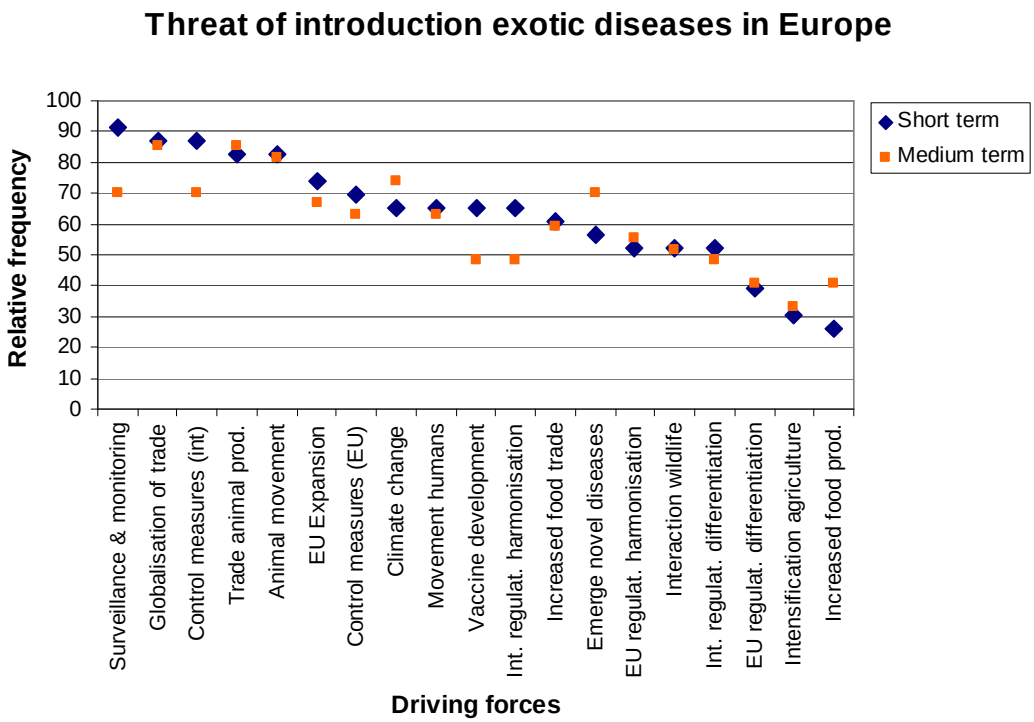

Figure 5a. Relative frequency of selected drivers to the *threat of introduction exotic diseases in Europe*.

Antibiotic resistance (Other emerging threats)

Antibiotic resistance is mostly influenced by drivers related to regulatory issues in the medium term (*increased surveillance and monitoring*, and *increased control measures in the EU)*. The incidence of antibiotic resistance may decrease due to these measures.

None of the drivers reached the frequency threshold in the short term, as in the medium term antibiotic resistance is connected to drivers related to regulatory issues this may suggest that participants thought that this threat can only be resolved through administrative measures. As such administrative measures take time, it is to no surprise that both were regarded as to influence in the medium term.

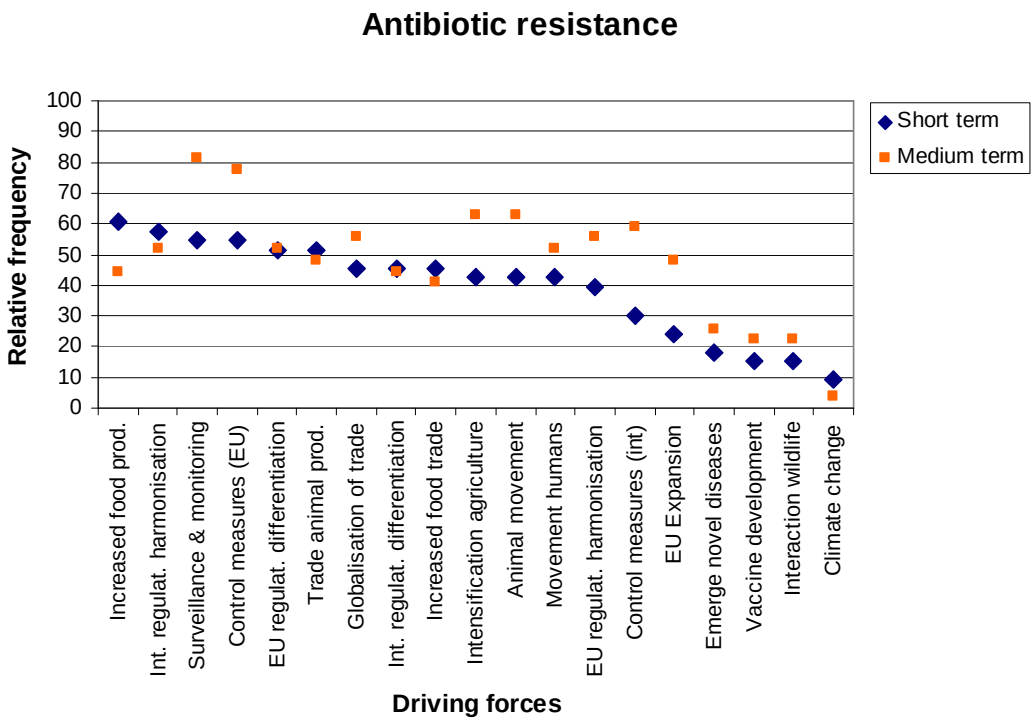

Figure 5b. Relative frequency of selected drivers to *Antibiotic resistance.*

Emerging & re-emerging agents (Other emerging threats)

The results suggest that with regard to both the short and medium term *increased movement of animals*, and *increased globalisation of trade*, will influence this threat by increasing its incidence. In addition, *increased surveillance and monitoring* will control emerging and re-emerging agents.

Furthermore, in the short term, *EU expansion*, and *increased trade in animal products*, were evaluated as potentially increasing the incidence of these agents. In contrast, *increased control measures in the EU,* and *novel vaccine development,* were thought to control emerging and re-emerging agents in the short term.

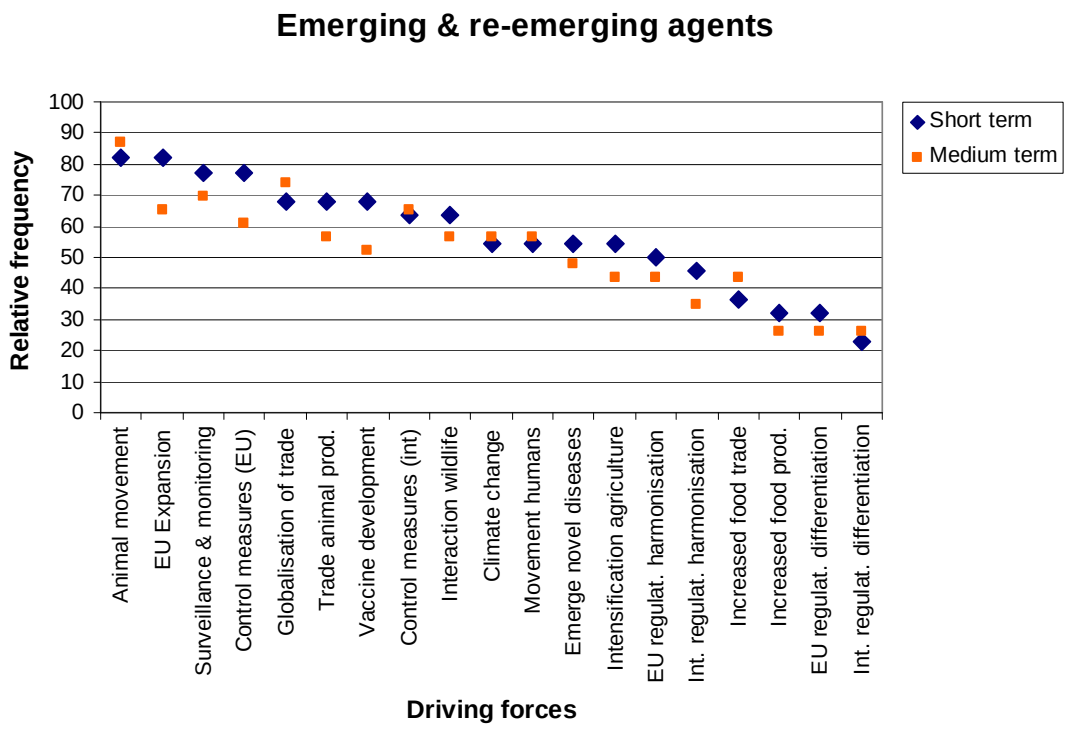

Figure 5c. Relative frequency of selected drivers to the *Emerging and re-emerging agents.*

Zoonoses (Disease Agents)

The results suggest that the following drivers will increase the incidence of zoonoses in both the short and medium term: *increased globalisation of trade*, *increased trade in animal products*, *increased movement of humans*, *EU Expansion*, and *increased interaction between wildlife and production animals*. Nonetheless, *increased control measures in the EU* may lead to a decrease in incidence of zoonoses both in short and medium term.

It is notable that some drivers were identified by more than two thirds of the respondents as being important in the medium term. The incidence of zoonoses may increase as a result of *increased trade in food,* and *increased movement of animals*. Furthermore, measures taken through *increased surveillance and monitoring*, and both *European (EU) and international regulatory harmonisation in the area of animal health*, may lead to a decrease in incidence of zoonoses in the medium term. In addition, *increased European (EU) differentiation in animal health regulation* will influence zoonoses in the medium term. However, respondents were divided with regard to the direction of the effect on the incidence of infectious animal diseases (Table 4).

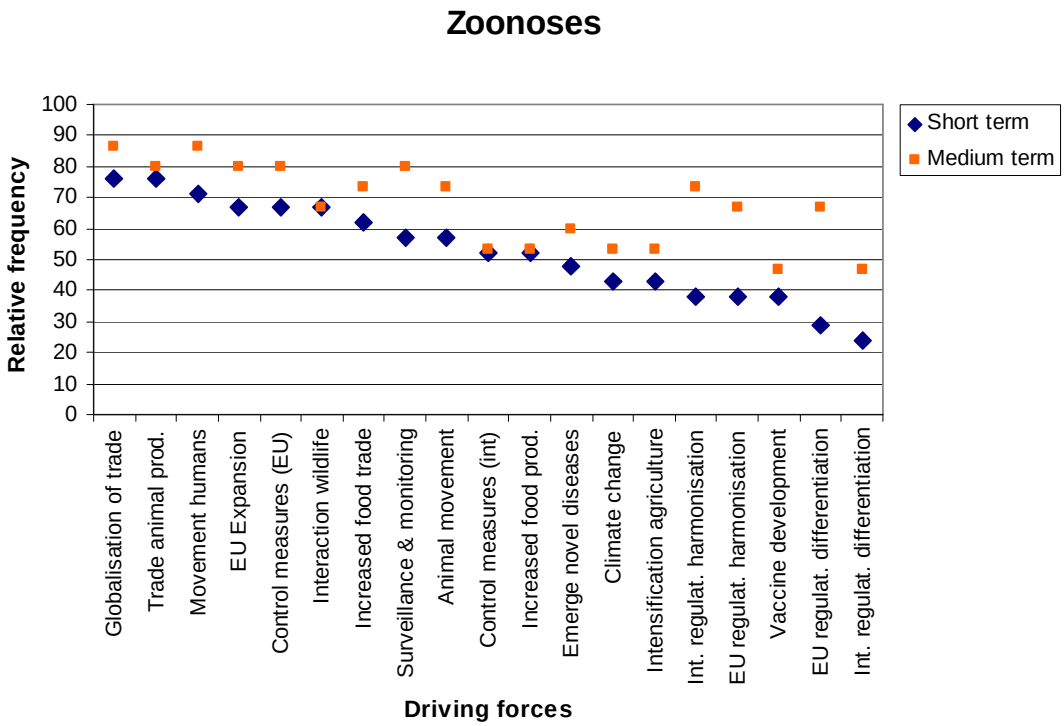

Figure 5d. Relative frequency of selected drivers to *Zoonoses*.

Arbovirus (Disease Agents)

The following drivers were identified by participants to influence arboviruses in both the short and medium term: *climate change*, *increased emergence of novel infectious animal diseases*, and *increased movement of animals*. All three drivers were thought to influence through increasing the incidence of arbovirus infections.

Furthermore, the incidence of arboviruses may be diminished in the short term through *increased surveillance and monitoring,* and in the medium term through *increased control measures in the EU*.

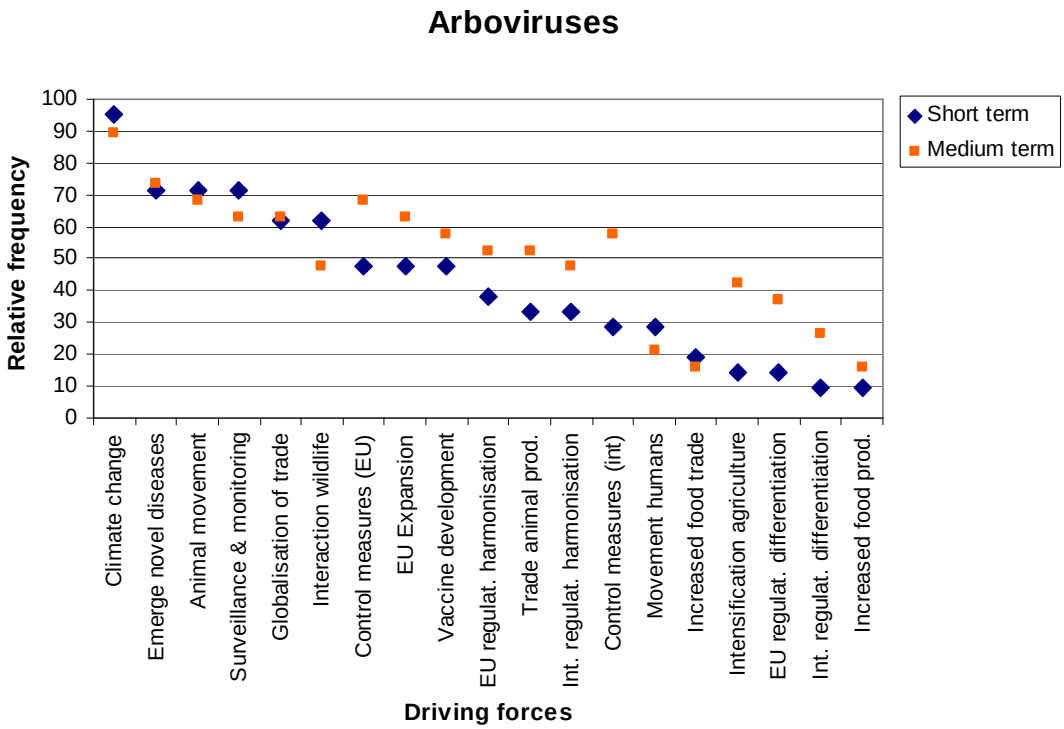

Figure 5e. Relative frequency of selected drivers to *Arbovirus*.

Vector borne diseases (Route of Transmission)

Climate change was thought to influence vector borne diseases in both the short and medium term. In addition, *increased movement of animals* was thought to influence vector borne diseases in the short term. Both drivers would influence by increasing the incidence of vector borne diseases.

Moreover, *novel vaccine development* represented an important medium term driver which may contribute to reducing the incidence of vector borne diseases.

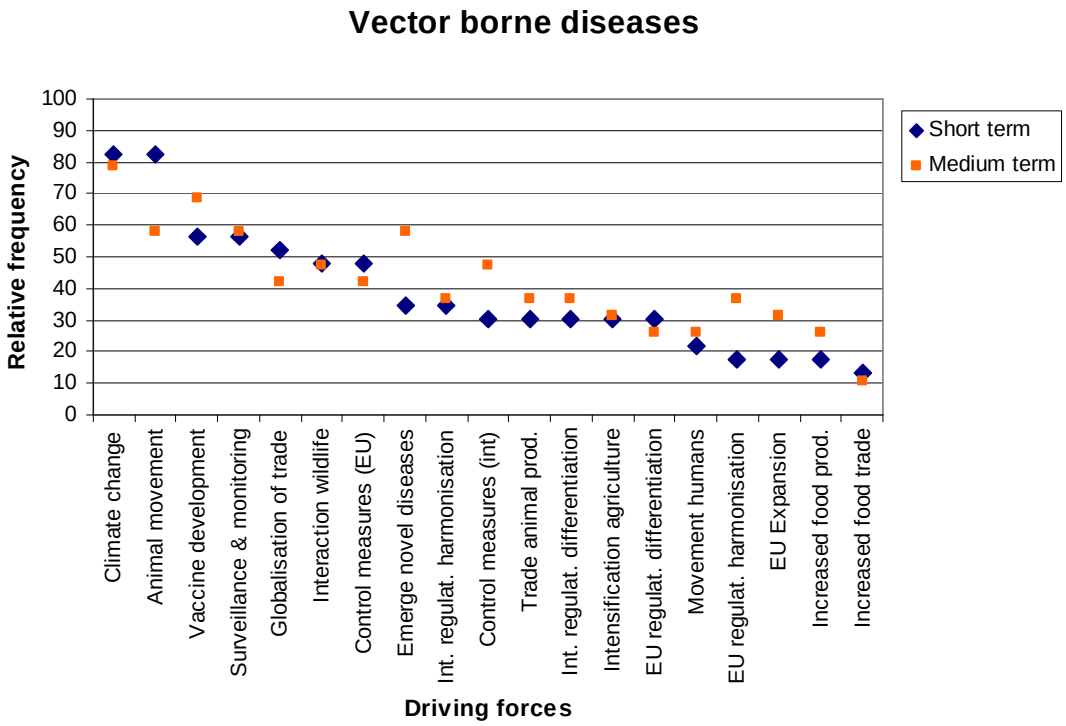

Figure 5f. Relative frequency of selected drivers to the *Vector borne diseases*.

Virus (Disease Agents)

The results suggest that the incidence of viruses will expand as a result of *increased movement of animals* in both the short and medium term. Yet, the prevention of virus introduction could be enhanced by *novel vaccine development*, and *increased (improved) surveillance and monitoring* in the short term.

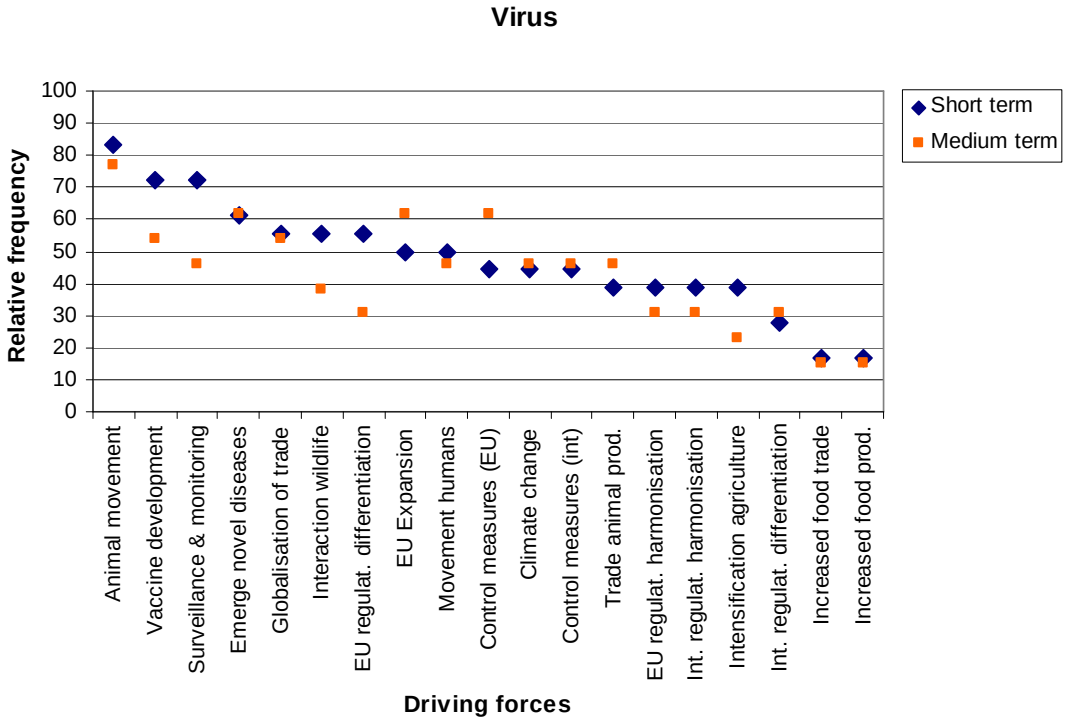

Figure 5g. Relative frequency of selected drivers to *Virus.*

Emerging unknown / novel pathogens (Other emerging threats)

Increased globalisation of trade, and *increased emergence of novel infectious animal diseases*, were all identified as drivers of emerging unknown and novel pathogens in the short and medium term. In addition, *increased movement of animals*, and in lesser extent *increased trade in animal products*, were identified as important drivers in both time frames, although mentioned more frequently in the medium term. All four drivers would increase the incidence of emerging unknown and novel pathogens.

Additionally, the incidence of the threat will increase due to *climate change*, and *increased interaction between wildlife and production animals* in the short term.

Yet, *increased control measures in the EU, increased surveillance and monitoring,* and *novel vaccine development*, were thought to reduce the incidence in the short term.

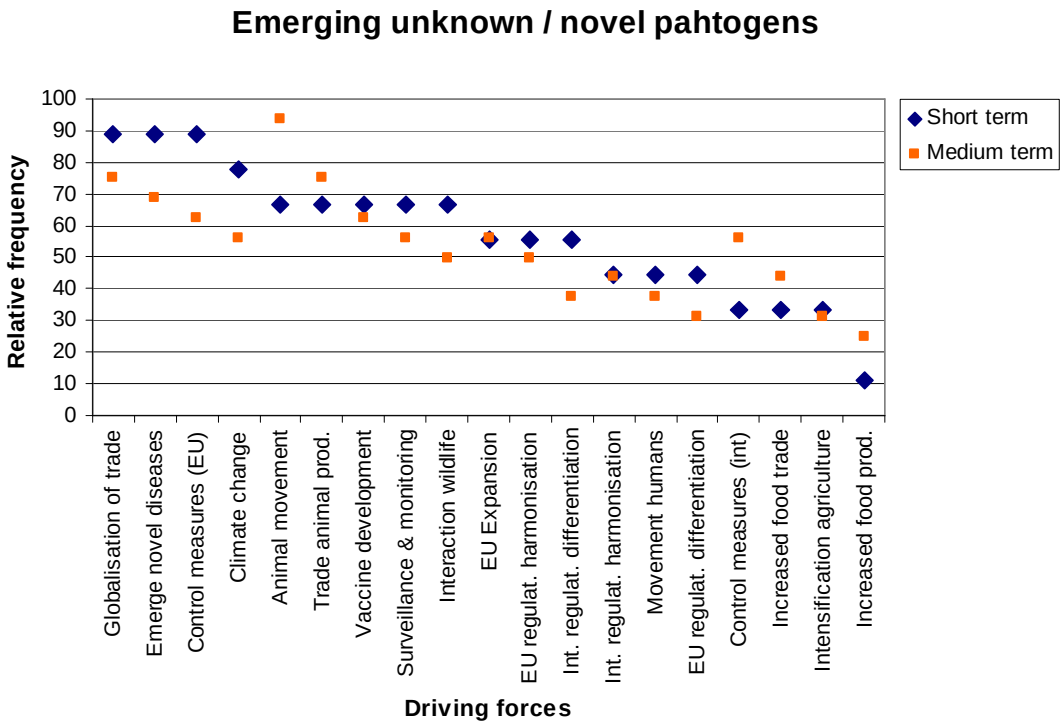

Figure 5h. Relative frequency of selected drivers to *Emerging unknown / novel pathogens.*

Prediction and preparedness for emerging infectious animal diseases

In the first round, about half of the expert participants (56%) disagreed that European capacity is adequate in terms of preventing infectious emerging animal diseases, and 21% agreed, Figure 6). A slight majority of respondents (49%) agreed that European capacity to identify emerging animal diseases is adequate, against 33% of participants who disagreed. There was less consensus regarding the adequacy of European capacity to prevent their occurrence.

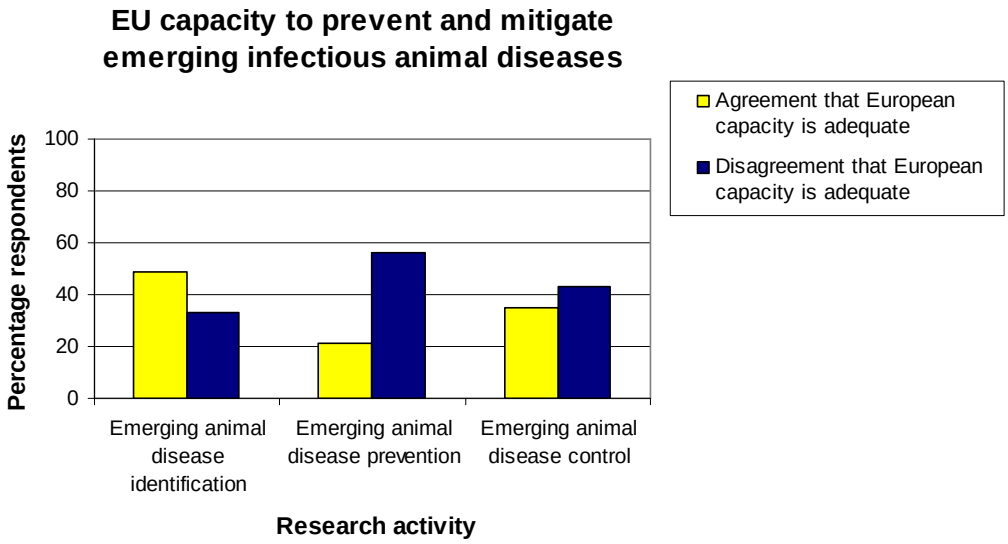

Figure 6. Opinions of experts regarding EU capacity to prevent and mitigate emerging infectious animal diseases.

In the second round these questions were rephrased and graphical feedback of the first round responses was provided. The majority of second round participants (83%) agreed that European capacity to identify emerging infectious animal diseases is greater than the European capacity to control them, and about half believed that the capacity to control emerging infectious animal diseases is greater than the European capacity to prevent them occurring. Against this, about one third (32%) indicated that they perceived the European capacity to prevent the emergence of animal diseases is greater than the European capacity to control them. A question arises as to where European resource should be directed in this regard.

Participants were requested to provide their opinion on four predictive methodologies in the first round. Participants thought that all four methodologies included in the questionnaire were useful when applied to the area of animal health (see Figure 7). Analysis of this item was not followed up in the second round.

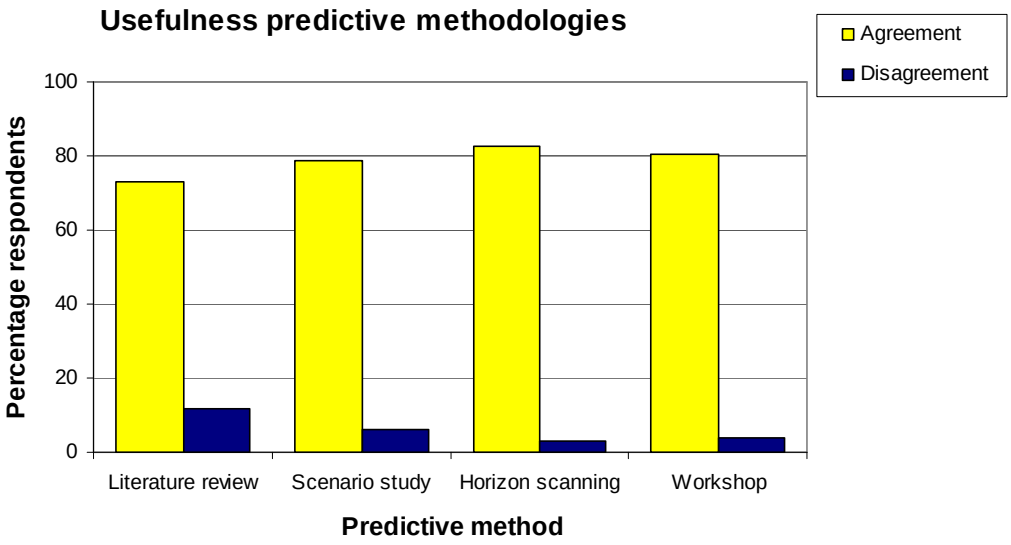

Figure 7. Usefulness predictive methodologies as used within the area of animal health.

Participants were asked to suggest additional potentially predictive methodologies. These are listed in Table 6 below.

Table 6. Predictive methodologies as proposed by round 1 Delphi participants.

- Epidemiological modelling
- Mathematical modelling
- Quantitative predictive modelling
- Laboratory investigations, field work
- Combination of methods
- The implementation of rapid world wide alert system
- Holistic systems that underlie emergence (and not pathogens)
- Risk mapping
- Risk analysis
- Simulation models

Future research topics relating to emerging infectious animal diseases

The question which focused on what research priorities regarding emerging infectious animal diseases need to be addressed at European level resulted in a long list of potential research topics and domains of which the condensed list can be found in Table 7. No significant differences were found for any of the issues, regarding whether they were short or medium term priorities. Some participants listed research disciplines rather than research priorities. These disciplines are, for the sake of completeness, also included in Table 7. Moreover, it is suggested that both disciplines and research priorities identified by the Delphi participants should be included in research programmes for further investigation.

Table 7. Research priority areas as included in the second round questionnaire, split over research priorities (*topical*) and research disciplines.

Research priorities	***Research disciplines***
Emerging diseases	Biology
Improve surveillance (diagnostics)	Climatology
Improve/develop early warning systems	Ecology
Improvements in emergency preparedness	Economics, related to animal health
Improvements in emergency response	Entomology
Pathogen-host interaction	Epidemiology
Pathogens related to zoonoses	Immunology
Resistance of pathogens to, e.g. anti-microbials	Risk analysis
Vaccine development	Virology
Vector related research	
Zoonoses (in general)	

Participants rated all future research topics (identified from the first round) as an important European research priority. In addition, it was expected that regional differences in opinions regarding research prioritisation would occur. Therefore, participants were divided across four bio-geographical regions of Europe according to their professional work location (regions were taken from the European Environment Agency: Atlantic, Central, Mediterranean, Northern/Baltic). However, no significant differences were observed between bio-geographical regions and between issues in either the short or medium term.

Discussion

Participants of the Delphi study thought that socio-economical factors, such as movement of animals, international trade, globalisation, interaction between wildlife and production animals, climate issues, and EU expansion, would increase the incidence of emerging infectious animal diseases. Furthermore, improved regulatory policy and natural science developments, such as novel vaccines, may help to reduce the incidence of such diseases. From this, one might conclude that (interdisciplinary) research which addresses both natural and social drivers of emerging infectious animal diseases needs to be developed if effective prevention and mitigation strategies are to be operationalised.

Threats related to the *Other emerging threats*, such as *antibiotic resistance* and the *threat of introduction of exotic diseases in Europe*, were thought to be most important. No significant differences were observed in this regard either in the short or medium term. Participants were asked to link these threats to relevant driving forces. Time frame differences were observed for only one threat, i.e. *Zoonoses* were more frequently connected to drivers in the medium term. No differences related to time were observed for the other threats.

Participants linked *the threat of introduction of exotic diseases in Europe* mostly to increased surveillance and monitoring, and international control measures in the short term, suggesting that as a driver such measurements would reduce the incidence. Additionally, this threat would be stimulated by increased (globalised) trade in animal products in both the short and medium term. *Antibiotic resistance* needs to be managed the medium term through increased surveillance and monitoring and European control measures. Participants linked increased movement of animals as key driver for *emerging and re-emerging agents.* Most drivers were thought to influence *zoonoses* in the medium term. Increased movement of humans and globalisation of trade were most frequently linked in this regard. Climate changes will mostly influence *arboviruses*, as well as, the directly related, *vector borne diseases* in both time frames[6]. In addition, increased animal movement may increase the incidence of arboviruses in both time frames, although for vectorborne diseases results show this only to be the case in the short term. The increased incidence of *viruses* arises primarily as a consequence of increased movement of animals in both the short and medium term, and participants suggested that mitigation may be most effective through application of increased surveillance and monitoring and novel vaccine development. In the short term, the incidence of *emerging unknown and novel pathogens* was thought to be primarily driven by globalisation of trade, and improved European control measures were seen as means to mitigate the risks. Increased movement of animals was identified to further increase the incidence of emerging unknown and novel pathogens in the medium term.

The results suggest that many participants perceived that European capacity regarding the prevention of emerging infectious diseases was less well developed than European capacity to control them which, in turn, was less effective than capacity to identify them. Whilst this result may appear self-evident, it provides empirical support for the conclusion that greater investment in prevention is an essential component of policy development and resource allocation.

[6] Arbovirus stands for arthropod borne virus and this is what is what is meant by vector borne too, and vectorborne diseases are caused by arthropod borne viruses. In this study the two have been separately identified as threat, and therefore included separately in this report.

The predictive methodologies included in the Delphi survey, (literature review, scenario study, horizon scanning, and workshops), were all thought to be useful when applied to the area of animal health and emerging infectious animal diseases. The methodologies suggested by participants mainly consisted of different types of data modelling, which provides a relatively simple platform to test in theory (possibly) complex real-world issues. In addition, data modelling allows for validation of issues one would like to plan to investigate in the field, and therefore may save resources, e.g. time or money, either immediately or in the future. Furthermore, participants suggested that using a 'combination of methods' (in other words, triangulation of results from different data streams) may facilitate the effectiveness of prediction. The use of triangulation may well lead to better outcomes as this may include also research from different domains, and again suggests that application of interdisciplinary research approaches is most likely to provide information relevant to the prevention and mitigation of emerging infectious animal diseases.

Participants identified in the first round a list of research priorities which they rated all as an important research priority in the second round. These priorities focussed mostly on improvements in emergency preparedness and, again, natural science developments, such as research relating to vaccine development, identification of vectors or emerging pathogens. In addition, participants identified research disciplines that may be involved in research into emerging infectious diseases. Participants identified both natural science inputs (for example, epidemiology or virology) as well as socio-economical disciplines, such as economics and risk analysis (i.e. risk communication and risk management).

From this it may be concluded that integration of natural and social scientific research is needed to resolve key the themes within emerging infectious animal diseases.

Delphi methodology is often applied to the development of consensus across an expert group regarding an issue or policy option. In the research presented here it has been employed at a more exploratory stage of research. As an exploratory study, some of the results may not be highly contentious. However, making implicit research priorities explicit through empirical analysis not only reflects and aggregates the views of disparate experts, but may also test assumptions which have not hitherto been questioned.

The differences between the short and medium term time frames were not profound. A broader differentiation between times might have provided a more distinct difference (e.g. Suk, Lyall, and Tait, 2008). Although, several participants noted that it was difficult (if not unfeasible) to foresee the future, regardless of a specification of time frames.

Lack of differentiation of results across bio-geographical regions was observed in the study. Although some trends towards differences in responses per region were identified, none were significant (and so were not reported in this document) possibly due to small sample sizes resulting from splitting responses into four different geographical areas. As this issue of differences in prioritisation of threats or research priorities is of policy relevance, further consideration of the potential impact of bio-geographical differentiation in policy may be needed.

Some limitations to the research can be identified. There was lack of consensus across the participant group regarding the (direction of) impact of some potential drivers of emerging infectious animal diseases across the sample. Ideally, these issues would have been further investigated in a subsequent round of the Delphi survey following provision of feedback from the second round. As the methodology adopted was confined to two rounds this was not possible. Alternatively, lack of consensus might indicate participant uncertainty regarding whether a specific issue was relevant, or uncertainty in the extent to which participants were certain of

their answer. Uncertainty analysis as described by Walshe and Burgman (2010) might help determine whether this was, indeed the case, and should be applied to future exercises. Given that the results from this Delphi study, including those were consensus did not occur, were presented to the participants of the subsequent consensus workshop, it may be assumed that further discussion regarding participant disagreement was discussed by workshop members.

Finally, a bias in responses may have been associated with the type of sampling used. Although a sampling frame which focused on multiple areas of expertise has been applied to select participants, most researchers reported their area of expertise to lie within animal diseases, veterinary medicine and epidemiology. In spite of the fact that great effort had been taken to ensure coverage across all pre-selected expertise areas, these three areas did dominate. The use of cascade-methodology (i.e. project members selecting participants from their personal networks) may have affected the final list as the project members have similar areas of expertise. In other words, more experts in certain areas of animal health were recruited as more experts in these areas were originally involved in the EMIDA network.

Conclusions

Within this study, increased movement of animals, increased surveillance and monitoring and increased control measures within the EU were the principal drivers to which the threats were connected. More specifically, increased movement of animals was identified as potentially increasing in the short term the incidence of vector borne diseases. Increased surveillance and monitoring may improve timely response to the introduction of viruses and exotic diseases in the short term. In addition, it may control zoonoses and antibiotic resistance in the medium term. Emerging pathogens, exotic diseases, antibiotic resistance, and emerging and re-emerging agents could be managed in the short term by 'increased control measures within the EU', which will also have a positive impact on the occurrence of arboviruses in the medium term.

Participants within this study have not only identified threats to animal health, but also identified possible mitigatory actions to reduce the negative impact of these threats. In order to control emerging infectious disease threats, resource allocation should increasingly focus on the development of effective policy measures regarding emergency preparedness. Furthermore, resources are needed to fund natural sciences development that support these risk management measures, such as research relating to disease agents, route of transmission (e.g. vector borne diseases), as well as socio-economic drivers of these threats. Participants have emphasised that socio-economic research is needed to understand drivers of emerging infectious animal diseases, as well as to develop control measures which are both socio-economic and technical. An interdisciplinary approach is required in the future if the mitigation and prevention of infectious animal diseases is to be optimised.

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Annex 1

EMIDA Delphi questionnaire round 1.

Dear participant,

Welcome to the online questionnaire! Many thanks for your willingness to participate in our research. The purpose of this survey is to understand your opinion regarding various issues relating to emerging infectious diseases of production animals. Before answering the questions, you will receive some more information about the aims of the project, together with some background information, on the next page.

Important information for filling in this survey:

- You can scroll through the questionnaire by pressing the *"Next"* and *"Back"* buttons. Though to ensure you do not loose your answers on a page: *press 'next' before going back*!
- By pressing *"**Finish**"* on page 15 you finalise the questionnaire, which is then sent to us automatically.

Please note, when we provide feedback, individual comments will not be identifiable. All results will be anonymised.

As already mentioned in the invitation letter, we estimate it will take approximately 45 minutes to an hour to answer the questions.

If you have any difficulties with this questionnaire, or if you would like to have some extra information about the survey, please contact the survey team at the following E-mail address: Delphi.survey@wur.nl

Kind regards on behalf of EMIDA,

Prof. dr. Lynn Frewer Meike Wentholt, MSc.

Department of Social Sciences of Wageningen University
Marketing and Consumer Behaviour Group

Provide your **E-mail address** here:
Please note that your email address will be used for identification to send you a notification of the next stages in the process and feedback.

General introduction

EMIDA
In the Seventh Framework Programme of the European Union, a European Research Area Network (ERA-NET) for coordination of animal health research has been set up: Emerging and Major Infectious Diseases of Livestock (EMIDA ERA-NET).

One objective of EMIDA is the development of a common Strategic Research Agenda (SRA). Research topics will be identified based on the most important priorities in terms of (future) threats to livestock (production animals) and related human health, and the current research gaps. Moreover this SRA should be developed in such a way that it will become a tool to manage research priorities in the long term.

Therefore, apart from setting up a more permanent organisation for future research programming on a European level, a review and analysis of existing foresight studies on the identification of (re-)emerging risks has been carried out by the EMIDA team.

This first step in the development of the SRA is now followed by an expert consultation study to collect and collate additional points of view regarding Emerging and Major Infectious Diseases of Livestock which have general support from a wide range of experts. On that account, I would like to thank you for participating in this expert consultation.

The final step in 'SRA-building' will be to achieve *consensus* on the points identified in the analysis of existing foresights and the expert consultation, or *identifying* areas where there is *disagreement* in the research community. This will be realised by evaluating the differences and similarities and subsequently organising a consensus workshop in spring of 2010 to go over these subjects for debate.

Holistic approach
As part of EMIDA activities, 44 existing foresight exercises have been reviewed. The results have indicated that a holistic approach is needed if good information about the driving forces and future threats is to be obtained. This implies that application of multidisciplinarity and interdisciplinarity research and knowledge is required to identify the relevant issues pertinent to developing the SRA. So, expert consultation will not only address veterinary experts, but representatives of other disciplines, such as agro-economists, animal welfare experts, ecologists, entomologist and many others, as well.

Drivers and threats
Evaluating existing foresight studies provided a long list of drivers, threats and future research topics. Various authors clearly have various definitions of both drivers and threats. In some instances, items are called drivers in one reference and threats in the other. Climate change is one such example. As guidance in the current exercise, definitions for drivers and threats are provided to help everyone think and speak in

the same 'language'. For both definitions, possible adverse human health effects need to be taken into consideration.

Driver: a driver or driving force is an external condition acting on a large scale (climate, energy, technology, social events, …), which has the potential to directly or indirectly influence animal and human health (in this case the (re)-emergence of infectious diseases).

Threat: a threat is a hazard that affects directly (or indirectly) animal and / or human health, like a pathogen, pathogen-carrier or a (bio)terrorism event.

The adoption of a holistic approach will facilitate identification of large scale influences. Some examples of such influences are climate change, changes in demographic situation (urbanisation), changes in land use and changes in economic conditions. Some of these may have a more direct influence on animal health than others, but in the end it is important to identify *all* potentially relevant changes, as well as to predict how and when these may be influential, in order to prepare ourselves for the future.

The scope of the EMIDA project, and thereby of this study, includes emerging and major infectious diseases of production animals, including fish and bees and including those conditions that pose a threat to human health.

Role of participants
In the process of developing a common SRA, it is necessary to identify and predict the changes we can expect to happen in the (near) future. We need consensus on this. Moreover, it is important to identify consensus and lack of consensus about (un)certainty of the expected changes, using this knowledge to prioritise research topics within the SRA.

We challenged ourselves by setting ambitious objectives in developing a strategic research agenda for Europe on emerging and major infectious animal diseases. Your contribution to this process is essential, because the input and effort of an array of experts from various disciplines is essential in the generation of an SRA that will be valid for the next 10-15 years.

I would like to thank you in advance for your effort.

Wim Ooms, DVM
ERA-NET EMIDA

SECTION 1. Driving forces on future threats to animal health

In section 1 we would like you to suggest some *driving forces* that, in your opinion, might result in changes in infectious animal diseases within the next 10-15 years in Europe.

A **driver** or **driving force** is defined in this study as an external condition acting on a large scale (climate, energy, technology, social events, …), which has the potential to directly or indirectly influence animal and human health (in this case the (re)-emergence of infectious diseases).

If you have no opinion regarding a particular issue, please indicate this by writing "no opinion" in the space provided.

1a. Please name up to five driving forces that you think will provoke changes *in general* in Europe in the next 5 years.

1b. Please name up to five driving forces that you think will provoke changes *in general* in Europe in 10-15 years.

2a. Please name up to five driving forces that you think will provoke changes in *infectious animal diseases* in Europe in the next 5 years.

2b. Please name up to five driving forces that you think will provoke changes in *infectious animal diseases* in Europe in 10-15 years.

3a. Please name up to five driving forces that you think will provoke changes in the *incidence of infectious animal diseases* in Europe in the next 5 years.

3b. Please name up to five driving forces that you think will provoke changes in the *incidence of infectious animal diseases* in Europe in 10-15 years.

SECTION 2. Future threats to animal health

In section 2 we will ask your opinion about *which* threats to animal health might become important in Europe in the next 10-15 years.

Threat: a threat is a hazard that affects directly (or indirectly) animal and / or human health. Examples include a pathogen, a pathogen-carrier or a (bio)terrorism event.

Please keep in mind that the scope of the project includes *emerging and major infectious diseases of production animals, including fish and bees and includes those conditions that pose a threat to human health*.

If you have no opinion regarding a particular issue, please indicate this by writing "no opinion" in the space provided.

4a. Name up to five infectious animal diseases that may become more threatening to *animal health* in the next 5 years.

4b. Name up to five infectious animal diseases that may become more threatening to *animal health* in 10-15 years.

5. We would also like to know whether there are any infectious animal diseases that are likely (in either 5 or 10-15 years time) to have a negative impact on each of the following areas: human health; food security (*availability* of food); food safety; social impact; economic impact; animal welfare.

5a1. Name up to five infectious animal diseases that may become more threatening to ***human health*** in the next 5 years.

5a2. Name up to five infectious animal diseases that may become more threatening to ***human health*** in 10-15 years.

5b1. Name up to five infectious animal diseases that may become more threatening to ***food security*** (*availability* of food) in the next 5 years.

5b2. Name up to five infectious animal diseases that may become more threatening to ***food security*** (*availability* of food) in 10-15 years.

5c1. Name up to five infectious animal diseases that may become more threatening to ***food safety*** in the next 5 years.

5c2. Name up to five infectious animal diseases that may become more threatening to ***food safety*** in 10-15 years.

5d1. Name up to five infectious animal diseases that may have a ***negative social impact*** in the next 5 years.

5d2. Name up to five infectious animal diseases that may have a ***negative social impact*** in 10-15 years.

5e1. Name up to five infectious animal diseases that may have a ***negative economic impact*** in the next 5 years.

5e2. Name up to five infectious animal diseases that may have a ***negative economic impact*** in 10-15 years.

5f1. Name up to five infectious animal diseases that may become more threatening to ***animal welfare*** in the next 5 years.

5f2. Name up to five infectious animal diseases that may become more threatening to ***animal welfare*** in 10-15 years.

5g1. You have considered seven topics that may be influenced by infectious animal diseases in the next 5 years:

- o Animal health
- o Animal welfare
- o Economic impact
- o Food security
- o Food safety
- o Human health
- o Social impact

In your opinion, have any other important topics been omitted from this list? If so, please list these below.

5g2. You have considered seven topics that may be influenced by infectious animal diseases in 10-15 years:

- o Animal health
- o Animal welfare
- o Economic impact
- o Food security
- o Food safety
- o Human health
- o Social impact

In your opinion, have any other important topics been omitted from this list? If so, please list these below.

Section 3. Prediction and preparedness for emerging infectious animal diseases.

In section 3 we ask you some questions regarding preparedness for emerging infectious animal diseases and their prediction.

If you have no opinion regarding a particular issue, please indicate this by ticking the "no opinion"-box.

6. Please give your opinion about the following statements:

6a. Existing European capacity to identify new or unknown infectious animal diseases is adequate.

Completely agree 1	Agree 2	Neither 3	Disagree 4	Completely disagree 5	No opinion 6

Please explain your answer by giving some examples.

6b. Existing European capacity to prevent new or unknown infectious animal diseases occurring is adequate.

Completely agree 1	Agree 2	Neither 3	Disagree 4	Completely disagree 5	No opinion 6

Please explain your answer by giving some examples.

6c. Existing European capacity to control new or unknown infectious animal diseases is adequate.

Completely agree 1	Agree 2	Neither 3	Disagree 4	Completely disagree 5	No opinion 6

Please explain your answer by giving some examples.

7. The EMIDA consortium has identified from the literature a list of *predictive methodologies currently used within the area of animal health*. We have used this list to develop the following questions.

Please consider our *definitions of the following methodologies.*

Predictive Methodologies
Literature review: Providing an overview of (published) study results (information or data sources) regarding a specific topic of (future) interest. The review may follow a specific type of structure for collating and analysing the relevant literature. Such studies may vary in terms of timescale, domain, topic, literature / information used. In addition, the aim of the literature review may vary. For example, such aims may include performing a "gap analysis" for priority setting.
Scenario study: involves bringing together (expert) stakeholders in order to get people to *map* possible outcomes of a particular future scenario. Scenarios are stories that represent some future event. Such studies may vary in terms of timescale, domain, topic, and presence / absence of structured guidelines (e.g. for the storyline), and by whether the scenario is created by the researcher or the participants. Scenarios can help to get people to consider what they would do given an unfavourable forecast, as well as that scenarios can be used to gain acceptance of forecasts.
Horizon scanning: consideration f future risks based on information from any source in order to identify priority areas and develop short-term projects (such as desk studies and expert workshops) to mitigate potential risks. Such 'horizon scans' may vary in terms of timescale, domain, topic, and methodology, but they are similar in the sense of scanning for information and extrapolating the results to the future. They may involve exploring novel and unexpected issues, as well as persistent problems or trends relevant to the topic.
Workshop: can be used for *future* plans, solving problems, or fact-finding (gathering knowledge). It is a meeting in which the selected stakeholders (participants) are the primary resource. Stakeholders are selected based upon their knowledge or relevant experience regarding the topic. A workshop is usually structured (through an agenda). A workshop differs from the methods defined above, by having a pre-defined topic set by the organiser.

7a. Please rate the following methods according to your opinion, with regards how useful they are for predicting the emergence of infectious animal diseases…
Please rate each method from 1 (completely agree) to 5 (completely disagree).

Methods		**Completely agree** 1	**Agree** 2	**Neither** 3	**Disagree** 4	**Completely disagree** 5	**No opinion** 6
1	Literature review						
2	Scenario study						
3	Horizon scanning						
4	Workshop						

7b. If you think that any other relevant methodologies have been omitted from this list, please list these here.

Section 4. Future research topics relating to emerging infectious animal diseases.

In section 4 we ask you some questions regarding research topics that ought to be addressed in the next 5 years and in 10-15 years in Europe.

If you have no opinion regarding a particular issue, please indicate this by writing "no opinion" in the space provided.

***** for instance: risk assessment, risk management, risk communication, surveillance, diagnostics, emergency preparedness and response, zoonoses, immunology, virology, climatology, economy, ...

8a. Research on what specific topics or domains*****, regarding emerging infectious animal diseases need to be addressed at European level *in the next 5 years*?

8b. Research on what specific topics or domains*****, regarding emerging infectious animal diseases need to be addressed at European level *in 10-15 years time*?

Section 5. General information.

In section 5 we will ask you some background information.
Please note that your name will only be used to send you an invitation to participate in the next survey. It will **not be possible** to relate your statements to *you* in the final report.

9. What is your gender?

Male
Female

10. Please indicate your age group:

20 – 35
36 – 45
46 – 55
56 – 65
66+

11. How would you describe your area of expertise? **Please select <u>one</u> for your main area of expertise.** If desired, you can also indicate additional areas of your expertise in the second column.

Discipline	Main area of expertise	Additional areas of expertise
Agro-economy		
Animal diseases, zoonoses (incl antimicrobial resistance)		
Veterinary medicine		
Virology		
Bacteriology		
Parasitology		
Entomology		
Epidemiology		
Immunology / vaccinology		
Animal genetics		
Animal welfare		
Communication		
Criminology (fraud, bioterrorism)		
Demography		
Food/Feed (e.g. production technology)		
Ecology / Nature conservation		
Mathematics (modelling)		
Meteorology / climate		
Public health		
Risk assessment		
Risk communication		
Risk management		
Sociology		
Wildlife		
Other: …….		
Other: …….		
Other: …….		

12. What is your current job description? (If retired, please state you last job description)

13. How many years of work experience do you have in this type of job?

< 5
6 – 10
11 – 15
16 – 20
21+

14. Country in which you work:

15. Do you have any comments about this questionnaire, please indicate them here:

Thank you for your participation!

Please note, by pressing *"**Finish**"* you finalise the questionnaire, which is then sent to us automatically.

You will receive an automatically generated E-mail message that invites you to return to your survey: **unfortunately this is not possible**.

If you do really need to make some changes, please contact us at delphi.survey@wur.nl.

Annex 2

EMIDA Delphi questionnaire round 2.

Dear participant,

Welcome to the online questionnaire! Many thanks for your willingness to participate in our research. The purpose of this survey is to go into depth regarding some of the issues discussed in the first questionnaire.

In this questionnaire, you will receive some feedback about the results of the first questionnaire. Please read this before answering the questions in the different sections.

Important information for filling in this survey:

- You can scroll through the questionnaire by pressing the *"Next"* and *"Back"* buttons. To ensure you do not lose your answers on a page: *press 'next' before going back*!
- By pressing *"**Finish**"* on page 15 you will finish completing the questionnaire, which will then be sent to us automatically.

When feedback is provided, individual comments will not be identifiable. All results will be anonymised.

We estimate it will take approximately 30 -45 minutes to answer the questions.

If you have any difficulties with this questionnaire, or if you would like to have some extra information about the survey, please contact the survey team at the following E-mail address: Delphi.survey@wur.nl

Kind regards on behalf of EMIDA,

Prof. dr. Lynn Frewer Meike Wentholt, MSc.

Department of Social Sciences of Wageningen University
Marketing and Consumer Behaviour Group

Provide your **E-mail address** here:
Please note that your email address will be used for identification to send you a notification of the next stages in the process and feedback.

SECTION 1. Driving forces on future threats to animal health

In the first round, we asked which driving forces were likely to result in changes in animal health in Europe in the short and medium term. Based upon your responses, we have developed the following questions. Can you please answer these?

A **driver** or **driving force** is defined in this study as an external condition acting at a large scale (climate, energy, technology, social events, …), which has the potential to directly or indirectly influence animal and human health (in this case the (re)-emergence of infectious diseases).

If you have no opinion regarding a particular issue, please indicate this by indicating "no opinion" in the space provided.

QUESTION 1A.
Please indicate whether each of the following ***driving forces*** will increase or decrease the *incidence of infectious animal diseases* in Europe in the next 5 years.
Drivers are presented in a randomised order.
These possible drivers are, of course, not always independent of each other.

	Driving force	Increase incidence of infectious animal diseases *1*	Decrease incidence of infectious animal diseases *2*	No effect on incidence of infectious animal diseases *3*	No opinion *4*
a	EU Expansion				
b	European (EU) regulatory harmonisation in the area of animal health				
c	Increased surveillance and monitoring				
d	Increased emergence of novel infectious animal diseases				
e	Increased trade in animal products				
f	Increased trade in food				
g	Increased globalisation of trade				
h	Novel vaccine development				
i	Climate change				
j	Increased international differentiation in animal health regulation				
k	Increased control measures, **in** the EU				
l	Increased interaction between wildlife and production animals				
m	Increased movement of humans				
n	Intensification of agricultural production systems				
o	Increased movement of animals				
p	Increased control measures, **outside** of the EU				
q	International regulatory harmonisation in the area of animal health				
r	Increased food production				
s	Increased European (EU) differentiation in animal health regulation				

QUESTION 1B.

Please indicate whether each of the following ***driving forces*** will increase or decrease the *incidence of infectious animal diseases* in Europe in 10-15 years.

Drivers are presented in a randomised order.

These possible drivers are, of course, not always independent of each other.

	Driving force	Increase incidence of infectious animal diseases *1*	Decrease incidence of infectious animal diseases *2*	No effect on incidence of infectious animal diseases *3*	No opinion *4*
a	EU Expansion				
b	European (EU) regulatory harmonisation in the area of animal health				
c	Increased surveillance and monitoring				
d	Increased emergence of novel infectious animal diseases				
e	Increased trade in animal products				
f	Increased trade in food				
g	Increased globalisation of trade				
h	Novel vaccine development				
i	Climate change				
j	Increased international differentiation in animal health regulation				
k	Increased control measures, **in** the EU				
l	Increased interaction between wildlife and production animals				
m	Increased movement of humans				
n	Intensification of agricultural production systems				
o	Increased movement of animals				
p	Increased control measures, **outside** the EU				
q	International regulatory harmonisation in the area of animal health				
r	Increased food production				
s	Increased European (EU) differentiation in animal health regulation				

SECTION 2. Future threats to animal health

In the first round, we asked which threats to *animal health* might become important in the next 5 years, and within 10-15 years. We have categorised the responses and developed the following questions. Can you please answer these?

Threat: a threat is a hazard that affects directly (or indirectly) animal and / or human health. Examples include a pathogen, a pathogen-carrier or a (bio)terrorism event.

Please keep in mind that the scope of the project includes *emerging and major infectious diseases of production animals, including fish and bees and includes those conditions that pose a threat to human health*.

If you have no opinion regarding a particular issue, please indicate this by indicating "no opinion" in the space provided.

QUESTION 2A
Please indicate the extent to which you think each of the following represents an important threat to animal health, in the next 5 years?

	Threats	Very important	Important	Neither important nor unimportant	Unimportant	Very unimportant	No opinion
		1	*2*	*3*	*4*	*5*	*6*
	Family of agents						
1.	Arboviruses						
2.	Bacterial agents						
3.	Non zoonotic diseases						
4.	Parasites						
5.	Pestiviruses						
6.	RNA virus						
7.	Virus						
8.	Virus, endogenous						
9.	Zoonoses						
	Complex infections						
10.	Complex / multifactorial disorders						
11.	Digestive system disorders						
12.	Infectious abortigenic agents						
13.	Locomotory system diseases						
14.	Mastitis						
15.	Production diseases						
16.	Reproductive disorders						
17.	Respiratory disease complexes						
	Specific animal diseases						
18.	Aquaculture diseases, (fish, molluscs)						

19.	Bee diseases						
20.	Other animal diseases						
	Route of transmission						
21.	Airborne infections						
22.	Direct contact zoonoses						
23.	Food borne agents						
24.	Rodent borne diseases						
25.	Vector borne diseases						
26.	Water borne agents						
	Epidemiological situation						
27.	Antibiotic resistance						
28.	Bioterrorism						
29.	Emerging & re-emerging agents						
30.	Emerging unknown / novel pathogens						
31.	Endemic diseases in Europe (threat of dissemination in Europe)						
32.	Increase in virulence						
33.	Opportunistic diseases						
34.	Threat of introduction exotic diseases in Europe						

QUESTION 2B
In question 1A you have been supplied a list of drivers (A-S), in question 2A you have been supplied a list of threats (1-34).

Using this list could you please identify, in the table below, what you consider to be the top 3 threats of most concern to animal health over the next 5 years.
Please use the numbers of question 2A above for your reference.

Threat 1	…
Threat 2	…
Threat 3	…

Next, could you please identify any drivers that you feel will influence these threats.

Drivers		**Please select the drivers that will have an impact on the threats you selected**		
		Threat 1	***Threat 2***	***Threat 3***
a	EU Expansion			
b	European (EU) regulatory harmonisation in the area of animal health			
c	Increased surveillance and monitoring			
d	Increased emergence of novel infectious animal diseases			
e	Increased trade in animal products			
f	Increased trade in food			
g	Increased globalisation of trade			
h	Novel vaccine development			
i	Climate change			
j	Increased international differentiation in animal health regulation			
k	Increased control measures, **in** the EU			
l	Increased interaction between wildlife and production animals			
m	Increased movement of humans			
n	Intensification of agricultural production systems			
o	Increased movement of animals			
p	Increased control measures, **outside** of the EU			
q	International regulatory harmonisation in the area of animal health			
r	Increased food production			
s	Increased European (EU) differentiation in animal health regulation			

QUESTION 3A

Please indicate the extent to which you think each of the following represents an important threat to animal health, in 10-15 years?

	Threats	Very important	Important	Neither important nor unimportant	Unimportant	Very unimportant	No opinion
		1	*2*	*3*	*4*	*5*	*6*
	Family of agents						
1.	Arboviruses						
2.	Bacterial agents						
3.	Non zoonotic diseases						
4.	Parasites						
5.	Pestiviruses						
6.	RNA virus						
7.	Virus						
8.	Virus, endogenous						
9.	Zoonoses						
	Complex infections						
10.	Complex / multifactorial disorders						
11.	Digestive system disorders						
12.	Infectious abortigenic agents						
13.	Locomotory system diseases						
14.	Mastitis						
15.	Production diseases						
16.	Reproductive disorders						
17.	Respiratory disease complexes						
	Specific animal diseases						
18.	Aquaculture diseases, (fish, molluscs)						
19.	Bee diseases						
20.	Other animal diseases						
	Route of transmission						
21.	Airborne infections						
22.	Direct contact zoonoses						
23.	Food borne agents						
24.	Rodent borne diseases						
25.	Vector borne diseases						
26.	Water borne agents						
	Epidemiological situation						
27.	Antibiotic resistance						
28.	Bioterrorism						
29.	Emerging & re-emerging agents						
30.	Emerging unknown / novel pathogens						
31.	Endemic diseases in						

	Europe (threat of dissemination in Europe)						
32.	Increase in virulence						
33.	Opportunistic diseases						
34.	Threat of introduction exotic diseases in Europe						

QUESTION 3B
In question 1B you have been supplied a list of drivers (A-S), in question 3A you have been supplied a list of threats (1-34).

Using this list could you please identify, in the table below, what you consider to be the top 3 threats of most concern to animal health in 10-15 years.
Please use the numbers of question 3A above for your reference.

Threat 1	…
Threat 2	…
Threat 3	…

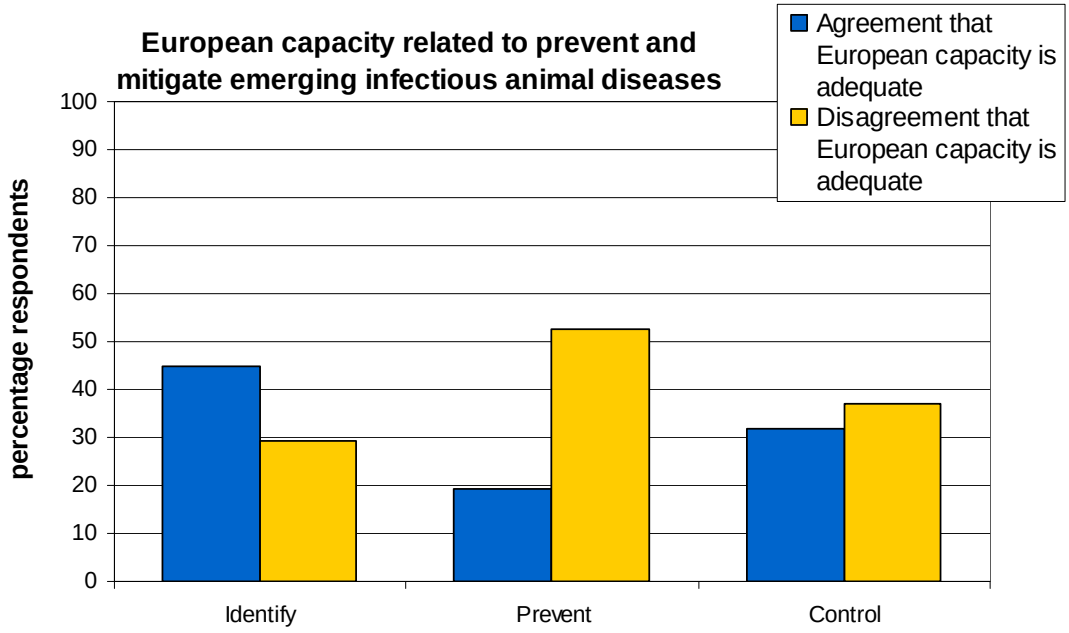
Next, could you please identify any drivers that you feel will influence these threats.

Drivers		**Please select the drivers that will have an impact on the threats you selected**		
		Threat 1	***Threat 2***	***Threat 3***
a	EU Expansion			
b	European (EU) regulatory harmonisation in the area of animal health			
c	Increased surveillance and monitoring			
d	Increased emergence of novel infectious animal diseases			
e	Increased trade in animal products			
f	Increased trade in food			
g	Increased globalisation of trade			
h	Novel vaccine development			
i	Climate change			
j	Increased international differentiation in animal health regulation			
k	Increased control measures, **in** the EU			
l	Increased interaction between wildlife and production animals			
m	Increased movement of humans			
n	Intensification of agricultural production systems			
o	Increased movement of animals			
p	Increased control measures, **outside** of the EU			
q	International regulatory harmonisation in the area of animal health			
r	Increased food production			
s	Increased European (EU) differentiation in animal health regulation			

Section 3. Prediction and preparedness for emerging infectious animal diseases.

In the first round, we asked whether existing European capacity to *identify*, *prevent*, or *control* new or unknown infectious animal diseases occurring is adequate. The results are presented in the figure below.

If you have no opinion regarding a particular issue, please indicate this by indicating "no opinion" in the space provided.



The majority of participants tended to agree that existing European capacity to *identify* emerging animal infectious diseases is adequate, and that existing European capacity to *prevent* emerging animal infectious diseases is inadequate.

Based on these results we would like you to answer the following questions.

QUESTION 4A
Do you agree that European capacity to ***identify*** emerging infectious animal diseases is stronger than the European capacity to ***control*** them?

Yes	No	No opinion

Please explain your response.

QUESTION 4B

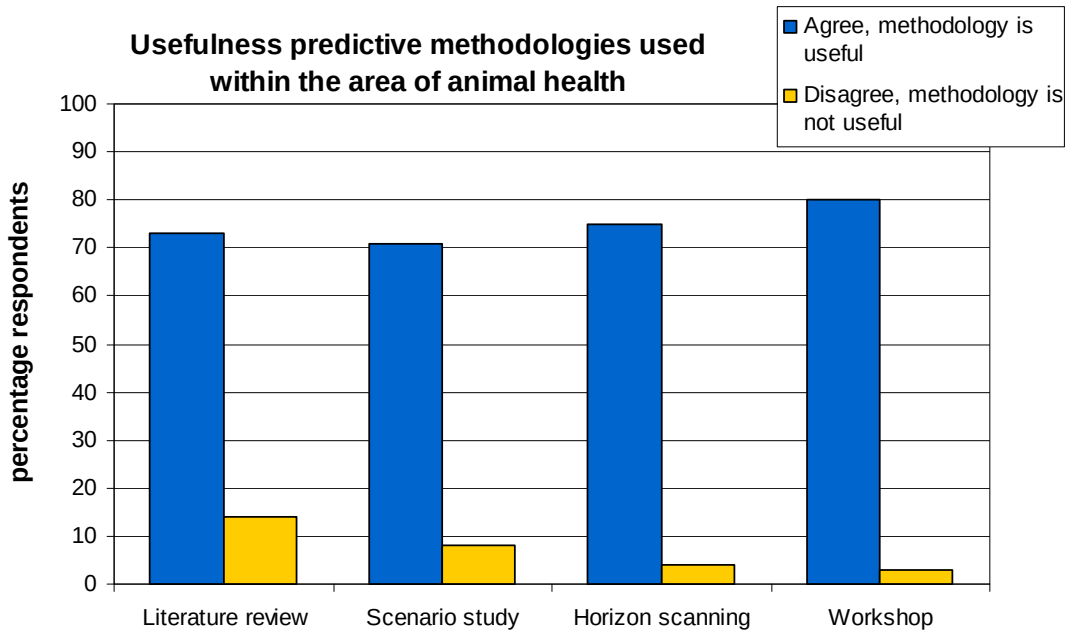
Do you agree that European capacity to *prevent* emerging infectious animal diseases is stronger than the European capacity to *control* them?

Yes	No	No opinion

Please explain your response.

The EMIDA consortium has identified from the literature a list of *predictive methodologies currently used within the area of animal health*.

Participants from the first round thought that all methodologies included in the questionnaire were useful when applied to the area of animal health.



In addition, the respondents have provided us with some additional methodologies, which we have incorporated in the following question.

QUESTION 5
Please indicate the extent to which you agree or disagree that each of the following methodologies should be the focus of increased resource allocation.

Methods		Completely agree **1**	Agree **2**	Neither **3**	Disagree **4**	Completely disagree **5**	No opinion **6**
1	Literature review						
2	Scenario study						
3	Horizon scanning						
4	Workshop						
5	Epidemiological modelling						
6	Mathematical modelling						
7	Quantitative predictive modelling						
8	Laboratory investigations, field work						
9	Combination of methods						
10	“The implementation of rapid world wide alert system”						
11	Holistic systems that underlie emergence (and not pathogens)						
12	Risk mapping						
13	Risk analysis						
14	Simulation models						

Section 4. Future research topics relating to emerging infectious animal diseases.

In section 4 we ask you some questions regarding research topics that ought to be addressed in the next 5 years and in 10-15 years in Europe.

If you have no opinion regarding a particular issue, please indicate this by indicating "no opinion" in the space provided.

QUESTION 6A.
In the previous round, research in the following areas was identified as European research priorities *in the next 5 years*? Do you agree?
Items are presented in a randomised order.

		Completely agree	Agree	Neither	Disagree	Completely disagree	No opinion
		1	*2*	*3*	*4*	*5*	*6*
1.	Risk assessment						
2.	Immunology						
3.	Virology						
4.	Economics, related to animal health						
5.	Ecology						
6.	Improvements in emergency preparedness						
7.	Epidemiology						
8.	Risk communication						
9.	Resistance of pathogens to, for example, anti-microbials						
10.	Biology						
11.	Vector related research						
12.	Risk management						
13.	Zoonoses (in general)						
14.	Pathogens related to zoonoses						
15.	Pathogen-host interaction						
16.	Emerging diseases						
17.	Improve/develop early warning systems						
18.	Climatology						
19.	Entomology						
20.	Improve surveillance (diagnostics)						
21.	Vaccine development						
22.	Studies at a molecular level						
23.	Improvements in emergency response						

QUESTION 6B.

In the previous round, research in the following areas was identified as European research priorities *in 10-15 years*? Do you agree?

Items are presented in a randomised order.

		Completely agree	Agree	Neither	Disagree	Completely disagree	No opinion
		1	*2*	*3*	*4*	*5*	*6*
1	Risk assessment						
2	Immunology						
3	Virology						
4	Economics, related to animal health						
5	Ecology						
6	Improvements in emergency preparedness						
7	Epidemiology						
8	Risk communication						
9	Resistance of pathogens to, for example, anti-microbials						
10	Biology						
11	Vector related research						
12	Risk management						
13	Zoonoses (in general)						
14	Pathogens related to zoonoses						
15	Pathogen-host interaction						
16	Emerging diseases						
17	Improve/develop early warning systems						
18	Climatology						
19	Entomology						
20	Improve surveillance (diagnostics)						
21	Vaccine development						
22	Studies at a molecular level						
23	Improvements in emergency response						

Section 5. General information.

In section 5 we will ask you some background information.
Please note, that your name will only be used to send you an invitation to participate in the next survey. It will not be possible to relate your statements to you in the final report.

7. Do you have any comments about this questionnaire, please indicate them here:

8. Would you like your institutional affiliation to be named in the report (as part of "participated institutions")?

As we have mentioned before, your *name* will only be used for administrative purposes, like to check whether you have responded and therefore do not need a reminder. It will **not be possible** to relate your statements to you or your institution in the final report.

If you would like your institutional affiliation to be named in the report, please provide in the space below the name of your institution.

9. Would you be interested in receiving any information regarding the results of this study, please tick the box below.

Thank you for your participation!

Annex 3

Institutional affiliation provided in agreement by round 2 participants.

- Austrian Agency for Health and Food Safety (AGES)
- Bayer Animal Health GmbH
- Biomedicine and Veterinary Public Health
- Biosciences Knowledge Transfer Network (UK)
- Cambridge University
- Central Veterinary Institute (CVI) of Wageningen UR
- Centre d'Ecologie fonctionnelle et évolutive (CEFE)
- Clinic for Swine Sheep and Goats University of Veterinary Medicine Hannover Germany
- CNRS
- Danish Agriculture and Food Council
- Danish Cattle Federation bb
- Danish Veterinary and Food Administration
- DGZ-Vlaanderen Unit DEO Torhout Belgium
- Kimron Veterinary Institute Veterinary Services and Animal Health Ministry of Agriculture, Israel
- Dutch National Centre for Monitoring of Vectors Dutch Ministry of Agriculture Nature and Foodquality
- Dutch Society for the Protection of Animals
- Faculty of Life Sciences University of Copenhagen
- Federal Veterinary Office Switzerland
- Field Station for Epidemiology of the University of Veterinary Medicine Hanover Foundation, Germany
- France AGRIMER
- French Agency for Food Safety
- French Agency for Veterinary Medicinal
- French Food Safety Agency (Afssa)
- French ministry of food agriculture and fisheries
- GD Animal Health Service
- Ghent University Belgium
- Hachaklait Veterinary Services Israel
- INRA Institut National de la Recherche Agronomique
- Institut für Hygiene und Infektionskrankheiten der Tiere Justus-Liebig-Universität, Giessen, Germany
- Institute for Animal Health
- Institute for the State Control of Veterinary Biologicals and Medicines, Czech Republic
- Institute of Virology and Immunoprophylaxis IVI 3147 Mittelhäusern Switzerland
- Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria Madrid (Spain)
- Intervet Schering Plough Animal Health
- ISPRA - Institute for Environmental Protection and Research (CLICORE Unit)
- Istituto Superiore di Sanità Rome Italy
- Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise (IZS A&M) Italy
- Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia-Romagna Brescia Italy
- Istituto Zooprofilattico Sperimentale della Puglia e della Basilicata
- Istituto Zooprofilattico Sperimentale delle Regioni Lazio e Toscana
- Istituto Zooprofilattico Sperimentale delle Venezie
- IZSUM - State Veterinary Institute fo Umbria and the Marches Italy
- JTI-Swedish Institute of Agricultural and Environmental Engineering
- Leibniz Institute for Farm Animal Biology Dummerstorf (FBN)
- Lithuanian Veterinary Academy
- Lohmann Animal Health GmbH & Co. KG Heinz-Lohmann Str. 4 27472 Cuxhaven
- Ministry of Agriculture and Forestry Finland

- National Reference centre wildlife diseases (CeRMAS) Istituto zooprofilattico sperimentale Piemonte Liguria e Valle d'Aosta QUART (AO) - ITALY
- National Veterinary Institute
- National Veterinary Institute Danish Technical University
- National Veterinary Institute Norway
- National Veterinary Institute Technical University of Denmark
- NEIKER-Tecnalia
- Nofima Marin
- Norwegian School of Veterinary Science
- Paul-Ehrlich-Institut Bundesinstitut für Impfstoffe und biomedizinische Arzneimittel
- Pig Research Centre Danish Agriculturel & Food Council
- Raisio Feed Ltd
- Royal Veterinary College London
- School of Veterinary Medicine Hannover Germany
- Swiss Federal Veterinary Office
- The Association for Animal Disease Prevention ETT ry
- TheState Veterinary Administration of the Czech Republic
- University College Dublin
- University of Veterinary and Pharmaceutical Science Brno
- University of Zurich Institute of Parasitology
- Veterinary Institute of LVA
- Wageningen University, Business Economics
- World Organisation for Animal Health (OIE)

Annex 4

Sample characteristics of Delphi study including those participating only to round 2 [a].

	Round 1		Round 2		Round 2 *only*	
Invited	217		143		69	
Participated	143		108		21	
Gender						
Female	33		30		3	
Male	107		98		18	
Age group						
20 – 35 years	8		7		2	
36 – 45 years	26		20		5	
46 – 55 years	73		56		9	
56 – 65 years	32		25		5	
66+ years	1		0		0	
Relevant work experience						
< 5 years	14		10		6	
6 – 10 years	22		20		3	
11 – 15 years	19		18		2	
16 – 20 years	32		25		3	
21+ years	46		37		8	
Region						
Atlantic	53		36		8	
Continental	26		21		1	
Mediterranean	27		23		3	
Nordic/Baltic	32		27		7	
Area of expertise [b]	***M***	***A***	***M***	***A***	***M***	***A***
Agro-economy	9	9	6	7	2	1
Animal diseases, zoonoses (incl. antimicrobial resistance)	46	28	36	25	5	5
Veterinary medicine	41	29	33	21	13	3
Virology	12	24	9	20	1	2
Bacteriology	13	23	11	21	1	3
Parasitology	7	16	7	15	1	2
Entomology	7	7	7	5	0	0
Epidemiology	23	29	16	24	1	2
Immunology / vaccinology	17	20	15	18	1	3
Animal genetics	8	3	7	3	1	0
Animal welfare	10	19	9	16	1	3
Communication	3	9	3	7	1	1
Criminology (incl. fraud, terrorism)	1	2	1	2	1	0
Demography	0	2	0	2	0	0
Food / feed	3	10	2	9	1	1
Ecology / nature conservation	4	9	2	7	0	1
Mathematics (incl. modelling)	2	14	1	12	0	2
Meteorology / climate	2	5	2	4	1	0
Public health	9	27	6	24	0	0
Risk assessment	22	36	22	35	0	3
Risk communication	3	15	3	12	0	2
Risk management	14	36	14	36	1	4
Sociology	2	2	1	2	0	0
Wildlife	5	20	3	15	1	2

[a] Not all participants filled in these questions.

[b] Participants were asked to provide one main area of expertise and provide –where needed – multiple additional areas of expertise. Some participants provided multiple responses to 'main area of expertise'. (M = main area of expertise; A= additional area of expertise)

Annex 5

Importance ratings future threats to animal health.

Overview of selected “top three threats” (valueas indicate frequency, given per category as well as per threat).

Categorised future threats		5 year	10-15 year
Disease agents	***Total for category:***	***82***	***65***
Arboviruses		21	19
Bacterial agents		3	3
Non zoonotic diseases		1	1
Parasites		3	2
Pestiviruses		0	4
RNA virus		13	7
Virus		18	13
Virus, endogenous		2	1
Zoonoses		21	15
Complex infections	***Total for category:***	***34***	***33***
Complex / multifactorial disorders		13	15
Digestive system disorders		3	3
Infectious abortigenic agents		1	0
Locomotory system diseases		2	2
Mastitis		2	1
Production diseases		4	5
Reproductive disorders		3	2
Respiratory disease complexes		6	5
Specific animal diseases	***Total for category:***	***5***	***11***
Aquaculture diseases, (fish, molluscs)		1	7
Bee diseases		4	4
Other animal diseases		0	0
Route of transmission	***Total for category:***	***42***	***39***
Airborne infections		5	6
Direct contact zoonoses		3	2
Food borne agents		9	8
Rodent borne diseases		0	0
Vector borne diseases		23	19
Water borne agents		2	4
Other emerging threats	***Total for category:***	***103***	***108***
Antibiotic resistance		33	27
Bioterrorism		2	3
Emerging & re-emerging agents		22	23
Emerging unknown / novel pathogens		9	16
Endemic diseases in Europe (threat of dissemination in Europe)		7	5
Increase in virulence		5	6
Opportunistic diseases		2	1
Threat of introduction exotic diseases in Europe		23	27

Annex 6.

Selected 'Top 3 threats' connected to relevant drivers.

List of threats to animal health (key to combined drivers-threats table)	
1	Arboviruses
2	Bacterial agents
3	Non zoonotic diseases
4	Parasites
5	Pestiviruses
6	RNA virus
7	Virus
8	Virus, endogenous
9	Zoonoses
10	Complex / multifactorial disorders
11	Digestive system disorders
12	Infectious abortigenic agents
13	Locomotory system diseases
14	Mastitis
15	Production diseases
16	Reproductive disorders
17	Respiratory disease complexes
18	Aquaculture diseases, (fish, molluscs)
19	Bee diseases
20	Other animal diseases
21	Airborne infections
22	Direct contact zoonoses
23	Food borne agents
24	Rodent borne diseases
25	Vector borne diseases
26	Water borne agents
27	Antibiotic resistance
28	Bioterrorism
29	Emerging & re-emerging agents
30	Emerging unknown / novel pathogens
31	Endemic diseases in Europe (threat of dissemination in Europe)
32	Increase in virulence
33	Opportunistic diseases
34	Threat of introduction exotic diseases in Europe

Selected threats combined with drivers.

5 year (own SUM order)		threats =>																															
drivers		**34**	**27**	**29**	**9**	**1**	**25**	**7**	**6**	**30**	**23**	**10**	**31**	**32**	**17**	**2**	**22**	**21**	**26**	**33**	**15**	**16**	**4**	**11**	**3**	**19**	**14**	**8**	**18**	**28**	**12**	**13**	**5**	**20**	**24**	*SUM DRIVERS*
Increased movement of animals	o	19	14	18	12	15	19	15	7	6	3	8	5	5	4	2	3	3	1	2	1	2	3	2	1			1	1							*172*
Increased surveillance and monitoring	c	21	18	17	12	15	13	13	7	6	5	6	2	4	5	3	1	1	2		3	2	1	1	1	1	1	1	1	1	1	2				*167*
Increased globalisation of trade	g	20	15	15	16	13	12	10	6	8	7	4	3	3	3	1	2	2	2	2	1	1	3	1		1		1			1					*153*
Increased control measures, in the EU	k	16	18	17	14	10	11	8	7	8	6	4	5	2	3	2	1		1	1	2			1		3	1		1	1	1					*144*
Increased trade in animal products	e	19	17	15	16	7	7	7	6	6	9	3	5	1	1	2	1	1	1	2	1			2	2		1									*132*
EU Expansion	a	17	8	18	14	10	4	9	6	5	6	4	5	1	4	2	1	1		2		2	1	1	1		1	1		2						*126*
Climate change	i	15	3	12	9	20	19	8	8	7	1	4	1	4		1		2	2	1		1	2		1	2	1	1	1							*126*
Increased emergence of novel infectious animal diseases	d	13	6	12	10	15	8	11	9	8	2	5	3	2	3	2	2					2	1	2			1	2	1	1	1					*122*
Increased interaction between wildlife and production animals	l	12	5	14	14	13	11	10	7	6	3	2		2	3	2	1	1	1	1		2	2	2	1				1	1						*117*
Increased movement of humans	m	15	14	12	15	6	5	9	6	4	4	3	2	3	1	1	2	2	1	2		1			1		1			2						*112*
Novel vaccine development	h	15	5	15	8	10	13	13	5	6		4	2	3	3	1	1	1	1			1						1	1	1	1					*111*
Intensification of agricultural production systems	n	7	14	12	9	3	7	7	3	3	5	8	3	3	2	2	2	3	2		4		2	1	2	1	1	2			1	2				*111*
International regulatory harmonisation in the area of animal health	q	15	19	10	8	7	8	7	4	4	4	2	2	3	3	2	2	1	1	1	1			1		2	1		1		1					*110*
Increased control measures, outside of the EU	p	20	10	14	11	6	7	8	5	3	6	1	4	2	2	2	2	1	1	1					1					1						*108*
European (EU) regulatory harmonisation in the area of animal health	b	12	13	11	8	8	4	7	3	5	2	3	2	2	3	2	1	1			1	1				1	1		1		1	1				*94*
Increased European (EU) differentiation in animal health regulation	s	9	17	7	6	3	7	10	4	4	3	5	2	2	1	1	3	1	1		1	1		1	1	1	1		1						*93*
Increased trade in food	f	14	15	8	13	4	3	3	5	3	9		2	1	1	1			1	2	1			1	1	1									*89*
Increased international differentiation in animal health regulation	j	12	15	5	5	2	7	5	3	5	6	4	1	3	2	1	3	1	1				1		2	1	1		1							*87*
Increased food production	r	6	20	7	11	2	4	3	4	1	4	5	4	2	2	1			1	1	1	1				1	1	1				2				*85*
SUM Threats		*277*	*246*	*239*	*211*	*169*	*169*	*163*	*105*	*98*	*85*	*75*	*53*	*48*	*46*	*31*	*28*	*22*	*20*	*18*	*17*	*17*	*16*	*16*	*15*	*15*	*13*	*11*	*11*	*10*	*8*	*7*	*0*	*0*	*0*	
10-15 year (own SUM order)		**threats =>**																																	
drivers		**34**	**27**	**29**	**9**	**1**	**30**	**25**	**7**	**6**	**10**	**23**	**32**	**31**	**26**	**2**	**18**	**21**	**15**	**17**	**5**	**22**	**11**	**19**	**28**	**16**	**3**	**33**	**8**	**4**	**14**	**13**	**12**	**20**	**24**	*SUM DRIVERS*
Increased movement of animals	o	22	17	20	11	13	15	11	10	5	8	5	4	5	3	1	1	4	2	4	2	2	3			2	1	1	1	2	1					*176*
Increased globalisation of trade	g	23	15	17	13	12	12	8	7	6	3	5	4	2		2	3	5	3	3	1	1	1	2	2		1	1	1	1	1					*155*
Increased surveillance and monitoring	c	19	22	16	12	12	9	11	6	4	4	5	2	2	4	3	3	2	3	3	1	1	3		2	1										*150*
Increased control measures, in the EU	k	17	21	14	12	13	10	8	8	4	5	6	1	4	3	3	2	2	3	1	2	2	2	1	1		1	1		1						*148*
Increased trade in animal products	e	23	13	13	12	10	12	7	6	5	4	5	2	2	1	2	2	2	3		1	1	1	1	2		1	1	1		1					*134*
Increased emergence of novel infectious animal diseases	d	19	7	11	9	14	11	11	8	7	7	3	3	1	2	2	2		1	2	2	1	1	2	2	1	2		1		1					*133*
EU Expansion	a	18	13	15	12	12	9	6	8	4	5	4	1	4	2	1		2	1	2	3	1	1		1	1		1	1		1					*129*
Climate change	i	20	1	13	8	17	9	15	6	7	4	2	3	1	4	1	4	3	1	1	1	1		3	1	1	1		1							*129*
Increased control measures, outside of the EU	p	19	16	15	8	11	9	9	6	5	2	6	2	3	2	3	1	1	1	1	2	1	2		1			1								*127*
Intensification of agricultural production systems	n	9	17	10	8	8	5	6	3	4	12	5	4	3	3	3	1	2	5	2	2	1	2	3		1			1			1				*121*
Novel vaccine development	h	13	6	12	7	11	10	13	7	5	6	2	5	2	2	3	3	3	1	3	1	1	1		1	1										*119*
European (EU) regulatory harmonisation in the area of animal health	b	15	15	10	10	10	8	7	4	5	2	5	2	3	1	3	2	3	1	2	1	1		1		1	1	1	1		1	1				*117*
Increased interaction between wildlife and production animals	l	14	6	13	10	9	8	9	5	6	4	3	4	1	4	2	1	1	4	2	1	1	2		2					1						*114*
Increased movement of humans	m	17	14	13	13	4	6	5	6	6	2	5	1	2	1	1		2		1	1	2			3			1			1					*107*
International regulatory harmonisation in the area of animal health	q	13	14	8	11	9	7	7	4	4	4	3	3	1	2	3	3	1		1	2	2	1	1		1										*105*
Increased European (EU) differentiation in animal health regulation	s	11	14	6	10	7	5	5	4	4	4	5	2	2	2	2		2	1	2	2	1	2	1	1	1				1						*99*
Increased trade in food	f	16	11	10	11	3	7	2	2	4	1	7	1	2	1	2	2	1	1		1	1	1	1	2		1	1	1							*93*
Increased food production	r	11	12	6	8	3	4	5	2	2	8	5	2	2	3	2	5	1	3		1			3	1	1		1				1				*92*
Increased international differentiation in animal health regulation	j	13	12	6	7	5	6	7	4	3	4	4	2	1	2	1	2	1	1	1	1	2	1		1	1				1						*90*
SUM Threats		*312*	*246*	*228*	*192*	*183*	*162*	*152*	*106*	*90*	*89*	*85*	*48*	*43*	*42*	*40*	*39*	*36*	*34*	*32*	*29*	*24*	*22*	*22*	*21*	*15*	*10*	*10*	*9*	*7*	*7*	*3*	*0*	*0*	*0*	

15 times or more selected 10-15 times selected