IMPACT OF CLIMATE CHANGE AND ENVIRONMENTAL CHANGE ON EMERGING AND RE-EMERGING ANIMAL DISEASES AND ANIMAL PRODUCTION

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***Summary**: Climate change and environmental change are a subset of the larger set of ecosystem changes that are promoting the emergence and re-emergence of animal diseases. The complexity of the interconnectedness between a wide range of factors influencing the emergence and re emergence of animal diseases means that uncertainty will continue to be a feature of the future. Central Veterinary Authorities responsible for disease preparedness and response thus need to develop systems and strategies that are adaptable, resilient and capable of dealing with the unexpected. They will need to focus on anticipating, preventing and responding to emerging and re-emerging animal diseases, irrespective of their cause. The responses to a recent questionnaire distributed to OIE Members revealed that most animal health officials are concerned by the impact of climate change and environmental change on emerging and re-emerging animal diseases. As expected, many Members identified a number of vector-borne diseases associated with climate change. Most Members indicated that the Central Veterinary Authority worked with other departments or agencies to address climate change and environmental change issues. Many OIE Members are not confident that veterinary institutions are effectively preparing professionals who are capable of understanding the impact of climate change and environmental change on emerging and re-emerging animal diseases. The responses to the questionnaire also indicated an almost unanimous support for OIE to do more to assist Members to address the issues of the impacts of climate change and environmental change on emerging and re-emerging animal diseases, including at the regional and sub-regional level. Most Members also indicated that they are keen to form their own ad hoc working or interest groups to address these issues.*

***Key words**:* climate change – environment – ecosystem – emerging infectious disease – animal disease – complex system – policy – strategy – resilience

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1. Introduction

The OIE has a mandate to improve animal health and welfare, and provides technical support to help the OIE Members to control and eradicate animal diseases, including diseases transmissible to humans. The OIE also offers expertise to help the poorest countries to control animal diseases that cause livestock losses, present a risk to public health, and threaten other Members.

To date, there has not been an overview of the attitudes and likely response frameworks of OIE Members to the dual challenge of climate change and environmental change[1] on animal production and health. A questionnaire was sent by the OIE to its Members to provide the opportunity of better understanding the current attitudes of the OIE Members.

This paper outlines global issues associated with the impact of climate change and environmental change on emerging and re-emerging diseases[2] of animals and animal production and summarises the responses from the questionnaire.

2. Context for this questionnaire

Many reports detail the current state of knowledge of ecosystem change, including both climate change and environmental change. For example, some of the key messages from the Millennium Ecosystem Assessment report [20] of 2005 are that:

- ✓ Humans have made unprecedented changes to ecosystems in recent decades to meet growing demands for food, fresh water, fiber, and energy.
- ✓ These changes have helped to improve the lives of billions, but at the same time they weakened nature's ability to deliver other key services.
- ✓ The pressures on ecosystems will increase globally in coming decades unless human attitudes and actions change.

Since the release of the Millennium Ecosystem Assessment report, the *Stern Review on the Economics of Climate Change* [27] was delivered in the United Kingdom and the fourth assessment of the Intergovernmental Panel on Climate Change (IPCC) was released [13]. Since 2005, a number of studies have reported that many of the anticipated consequences of climate change and environmental change seem to be occurring at a faster rate than expected [18]. For example, the rate of melting of the Greenland ice sheet and the retreat of glaciers on a near global scale has been dramatic and surprising [4, 15, 28]. In addition, there has been a recent detection of a surge in methane emissions associated with onset of soil freeze-in of permafrost-dominated tundra regions [19]. How important these new findings are in relation to global climate is still being determined. Similarly, researchers completed a comprehensive analysis of nearly 30,000 species and physical phenomena and concluded that worldwide changes in these systems were attributed to human-induced climate change [24], but the likely flow-on effects of these changes are uncertain.

In terms of disease, most reports on climate change focus on human health. In 2006, FAO[3] released a report, entitled *Livestock's Long Shadow* [26], that highlighted the role of the livestock sector in driving global environmental change, but this report did not focus on animal disease implications of global environmental change. In 2008, the OIE produced a volume of the *Scientific and Technical Review* on the expected impact of climate change on the epidemiology and control of animal disease [7]. This review is a valuable addition to the nascent literature dealing with climate change and animal disease. A number of the

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1 For the purposes of this technical item, the following definitions were applied:
- *Climate change:* A change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable periods. We considered that some aspects of climate variability, including increasing frequency and intensity of extreme weather events such as droughts and floods, were attributable to climate change.
- *Environmental change:* Refers to changes in major physical and biological systems, either caused naturally or influenced by human activity. This definition includes changes in land use (e.g. deforestation, land clearing, conversion of wetlands, soil degradation), water quality and quantity (e.g. overuse and pollution of water supplies), biodiversity (e.g. loss of species), and air quality (e.g. air pollution) but explicitly excludes climate change.

2 For the purposes of this technical item, the following definitions were applied:
- *Emerging infectious disease:* A new infectious disease resulting from the evolution or change of an existing pathogen or parasite resulting in a change of host range, vector, pathogenicity or strain; or the occurrence of a previously unrecognised disease.
- *Re-emerging infectious disease:* A known infectious disease that shifts or expands its geographical range, expands its host range, or significantly increases in incidence.

3 FAO: Food and Agriculture Organization of the United Nations

papers in this issue of the *Scientific and Technical Review* point out that many of the arguments relating to climate change are incomplete or simplified [6] and that the systems that are being investigated are complex and interconnected —clearly in the realm of 'complex systems' where establishing clear 'cause and effect' relationships is very difficult. However, it is not necessary to establish clear causal links between either climate change or environmental change and animal disease emergence before designing and implementing robust strategies to deal with disease emergence.

3. Causality

In December 2007, a public workshop on microbial threats, organised by the Institute of Medicine of the United States National Academies (IOM), examined the anticipated direct and indirect effects of global climate change and extreme weather events on infectious diseases of humans, animals, and plants [12]. This report highlighted that the 'web of causation' includes many factors that are closely interrelated or influenced (either directly or indirectly) by local, regional or global variations in climate. Climate change and environmental change are two of these interrelated factors.

It is thus not surprising that although the questionnaire explicitly defined climatic change and environmental change separately, the responses of many Members revealed that this distinction was quite problematic. In particular, the distinction was not very helpful for many Members when identifying emerging and re-emerging animal diseases believed to be directly associated with climate change or environmental change.

The questionnaire purposefully avoided issues surrounding causality. From a purely technical and scientific perspective, many scientists and commentators have reported that "direct causal connections have yet to be established between climate change and infectious diseases" [12]. Accurate predictions on the behaviour of an infectious disease cannot be made on the basis of climate projections (or observed environmental changes) alone. However, there has been much discussion and debate about how much evidence is required to establish causal associations with sufficient confidence so that decision-makers can act. A number of authorities have argued that the analysis of complex relationships such as disease emergence and ecological change requires new approaches that complement traditional epidemiological methods [9, 17, 23]. Such approaches include strong inference, causal diagrams, model selection and epidemiologic causal criteria. These approaches have been used to investigate large-scale drivers of disease emergence such as land-use change and climate change. Nonetheless, the question inevitably remains of how much information is required before a decision-maker should act. Decision makers will obviously take into account other issues such a social, economic and political factors in addition to science (and causality arguments).

Although much recent discussion has focused on the relationship between climate change and emerging infectious diseases (EIDs), this paper will not debate whether any particular disease emergence or re-emergence is conclusively due specifically to climate change or environmental change. Instead, it assumes that at a broader level, ecosystem change —which includes climate change, environmental change and the associated interrelationships— is strongly associated with many emerging and re-emerging animal diseases. This position is consistent with the growing consensus that although climate change has attracted much more attention, ecosystem change is the overarching issue that needs to be addressed [11].

4. Complex systems

In 2004, King referred to the convergence model of the IOM when classifying the factors affecting disease emergence and re-emergence [25]. The list of factors included microbial adaption and change; host susceptibility; climate and weather; changing ecosystems, demographics and populations; economic development and land use; international trade and travel; technology and industry; reduction in animal and public health services or infrastructure; poverty and social inequity; war and dislocation; lack of political will; and intent to do harm [16]. Again, many of the factors listed are interrelated and all are part of a complex system [29]. The relationships can be simplified —as they have been in the convergence model— or further teased apart, as they have been in many other models [e.g. 6, 9, 29].

Models are designed to help understand the relationships between factors and to improve anticipation of and preparedness for future developments and events. However, an understanding of complex systems means that decision-makers need to be more adept at dealing with complexity and surprises, uncertainties, resilience, vulnerability and adaption. Many scientists and policy makers are adjusting to working with incomplete information and dealing with 'uncertainty-based' policy decisions.

In this complex system environment, there are often no 'right decisions' but simply more suitable decision pathways. More broadly, social attitudes, values and actions influence the context within which decision-makers develop policy and strategy. Accordingly, many researchers working with emerging and

re-emerging animal diseases are now appreciating the key importance of considering social and ecological factors interactively rather than separately. To highlight this view, some scientists refer specifically to the complex system as the socio-ecological system or the ecosocial approach to health [22]. This is adaptive management in which 'policies become hypotheses' and management actions are used to test the hypotheses and readjust strategy as more information becomes available [10]. Central Veterinary Authorities will need to become more familiar with this approach when dealing with emerging or re-emerging animal diseases.

In order to keep these issues tractable, the simplified model in Figure 1 (see p 20) will be used as a basis of discussion for the rest of this paper. The relative width of the arrows in this figure reflects the level of influence that policy makers focused on emerging or re-emerging animal diseases are likely to exert within the overall system.

5. Main relationships

5.1. Relationship between climate change or environmental change and emerging or re-emerging animal diseases

The major relationship that the questionnaire addressed was the association between climate change or environmental change and the emergence and re-emergence of animal diseases shown by the arrow labelled 1 in Figure 1.

Most Members identified at least one emerging or re-emerging animal disease that was believed to be associated with climate change or environmental change. The most frequently mentioned diseases associated with climate change and environmental change are listed in Table 1.

Table 1.– Diseases that were believed to be associated with climate change or environmental change

Diseases mentioned more than twice as being believed to be associated with:	**Climate change**	**Environmental change**
Vector-borne		
Bluetongue	✓	✓
Rift Valley fever	✓	×
West Nile fever	✓	×
African horse sickness	✓	×
Lumpy skin disease	✓	×
Leishmaniosis	✓	✓
Epizootic haemorrhagic disease	✓	×
Tick-borne diseases	✓	✓
Parasitic diseases (excluding tick-borne)	✓	✓
Pasteurellosis	✓	×
Avian influenza	✓	✓
Anthrax	✓	✓
Blackleg	✓	×
Rabies	✓	✓
Tuberculosis	×	✓

The climate change responses are broadly consistent with other work that has highlighted the increase in the incidence of vector-borne diseases in association with climate change. This increase is due to both the markedly altered vector population size and dynamics, and the increases in pathogen replication rates that are influenced directly by ambient temperatures during infection of the poikilothermic arthropod vector [12].

5.2. Relationship between ecosystem change and animal production

The FAO report entitled *Livestock's Long Shadow* concluded that the livestock sector is one of the most significant contributors to the most serious environmental problems at all scales, ranging from local to global [26], corresponding to arrow 2 in Figure 1. Indeed, this report argued that livestock production should be a major policy focus when dealing with problems of climate change, land degradation, water shortage, water pollution and loss of biodiversity.

The relationship marked by arrow 3 in Figure 1 refers to the changes that societies choose to make in their animal production systems in response to the anticipated and observed changes in climate and the environment. There is obviously a very wide range of possible responses that can be implemented at the level of industry, country, and region. However, the general trend towards intensification and industrialisation is expected to continue as societies seek to improve efficiency and reduce the land area required for livestock production. With reference to aquatic animal production, the same arguments about efficiency and reducing the area available for animal production will apply. Each OIE Member will experience these trends to some degree, depending on its capacity to adapt to the challenges that lie ahead.

5.3. Relationship between animal production and emerging and re-emerging animal diseases

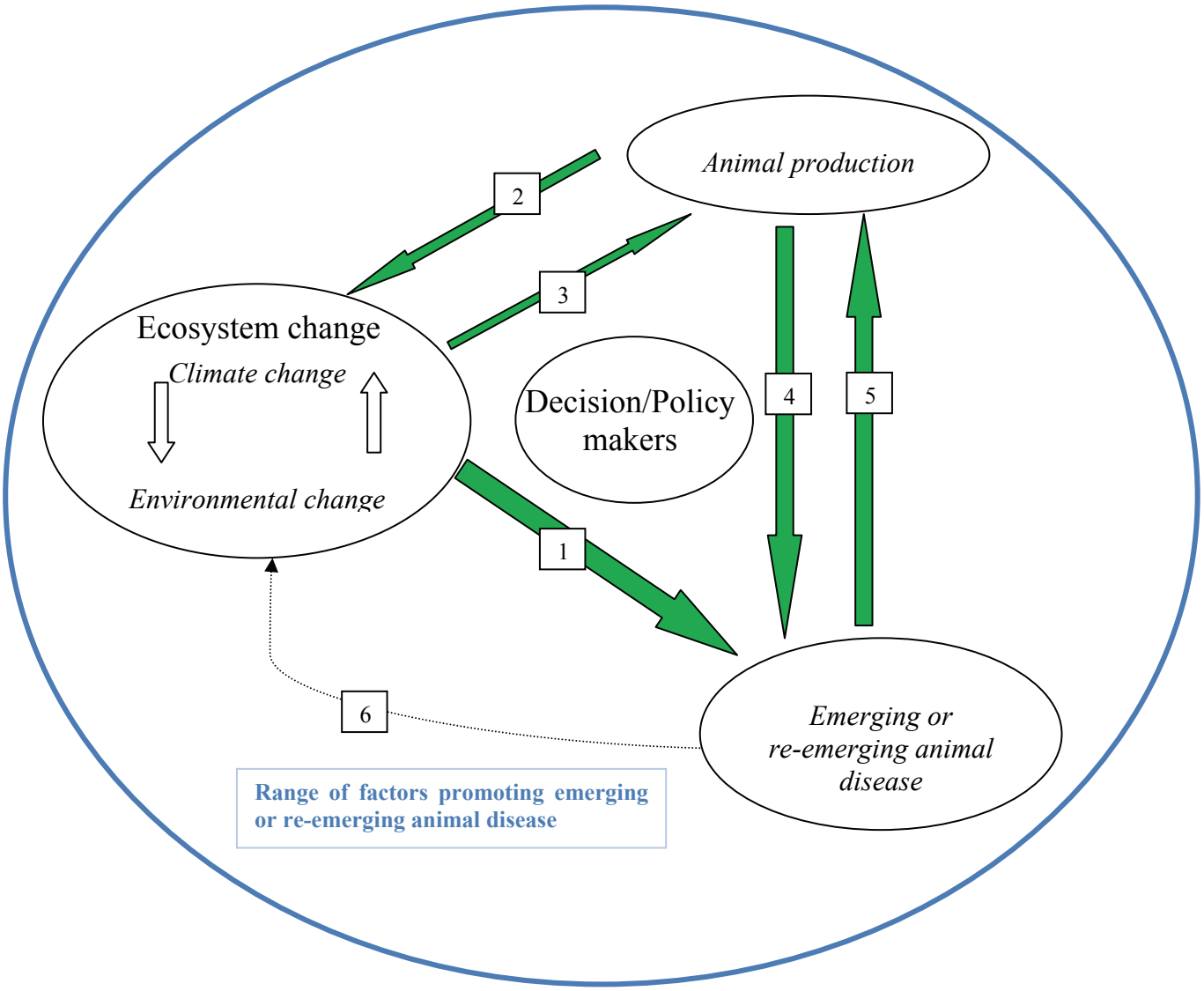
The relationship between animal production and emerging and re-emerging animal diseases was referred to in the questionnaire in the context of intensification of animal production as outlined in Section 5.2. above. Animal production systems have been responsible for many emerging and re-emerging diseases globally for hundreds of years. More recently, many integrated management programmes for animal diseases have been developed in response to the changing disease profiles associated with evolving animal production systems. For example, treatment regimes were developed to decrease the incidence of mastitis, which was closely correlated with a range of animal management factors focused on increasing milk production. Similar examples in intensive animal production systems include the prevention and treatment of bovine respiratory disease in feedlots, salmonellosis in poultry production systems, porcine reproductive and respiratory syndrome in pig production systems, internal parasites in more intensively raised sheep and goat populations, and white spot syndrome in prawns. These were all emerging diseases at one time, but in most cases these diseases are now established within the relevant production systems. In developing countries, the diseases of interest may differ, but the principle still applies.

In general, intensifying production systems will increase the opportunity for emerging and re-emerging animal diseases [21] and management systems need to be developed to minimise their direct and indirect effects on production and profitability. This means that in response to actual or anticipated emerging and re-emerging animal diseases, animal production systems will be adjusted or redeveloped (this is the relationship labelled 5 in Figure 1). The evolution of relationships 4 and 5 is in fact a continuous interplay in which changes in one element of the complex system lead to changes in other parts of the system.

5.4. Relationship between emerging and re-emerging animal diseases and ecosystem change

The policy decisions about emerging and re-emerging animal diseases that societies implement can indirectly influence ecosystem changes. For example, in countries attempting to eradicate a re-emerging disease such as bovine tuberculosis, control strategies could conceivably lead to changes in the density and distribution of other host species such as badgers, possums or buffaloes. These changes will have other flow-on effects within the ecosystem. This relationship is generally quite diffuse compared to the other relationships described and has therefore been marked as a dotted arrow in Figure 1.

Figure 1.– Main relationships between emerging and re-emerging animal diseases, climate change, environmental change and animal production



6. Policy responses

The interactions between the variables described in Figure 1 take place across a vast array of scales of time and space. The impacts can thus be very variable. For example, there is recognition that the impacts of climate change will not be evenly distributed across the globe [27]. In addition, the relationships are in a constant state of flux within a system that continues to evolve, making it difficult to forecast accurately the rate, distribution and scale of emergence and re-emergence of many animal diseases.

However, the emergence of some specific animal diseases such as arboviral diseases can be forecast with some confidence across a range of scales (i.e. country level, regionally and globally) [8, 12]. By contrast, when and where the next disease, such as, for example, severe acute respiratory syndrome (SARS) or Nipah virus disease, will emerge cannot be forecast with any precision. At the global scale, scientists investigating trends in emerging infectious diseases have confirmed that emergence is driven largely by socio-economic, environmental and ecological factors, and that zoonotic emerging infectious diseases represent an ”increasing and significant threat to global health” [14]. In addition, in recent years more than 70% of zoonotic emerging infectious diseases have originated from wildlife sources. Most worrying, is that the global allocation of surveillance resources is not based on risk, but strongly reflects the greater resources and capacity that exist in developed countries. This is also true of emerging or re-emerging animal diseases. Indeed, the veterinary profession has been asked whether the necessary surveillance systems are in place to deal with changing animal disease patterns [1].

The key policy response of Central Veterinary Authorities must be to improve surveillance and emergency response capacities to deal with this increasing rate of disease emergence and re-emergence irrespective of their cause. The OIE has played a critical role in addressing this issue by developing the PVS (Performance

of Veterinary Services) tool and encouraging its application across a wide range of Members [30]. This tool, using OIE international standards of quality and evaluation "promotes a culture of raising awareness and continual improvement". It assists the Central Veterinary Authorities of Members to argue for improved access to financial and human resource support to improve veterinary services. This work contributes directly to the 'global public good' nature of the prevention and control of animal disease. The PVS tool specifically addresses surveillance and emergency animal disease preparedness capacity issues and has potential to be used to help address the current imbalance in surveillance capacity and disease risk at both the country and regional levels. Once a more solid veterinary services platform is established, it will be possible to embed more formal risk management approaches that will lead to the development of more robust strategies that can deal with unexpected emerging or re-emerging animal diseases.

More generally, there is need to improve understanding of complex systems and the increasing importance of longer-term thinking and planning by both developed and developing Members. This need for longer-term thinking and planning should mean that foresight or futures approaches will be more fully embraced by animal health policy makers [3]. Such approaches will help Central Veterinary Authorities build more resilience into the frameworks and systems designed to anticipate, prevent and control emerging or re-emerging animal diseases. As part of this increased understanding of the larger system and the timeframes involved, policy makers will need to continue to network with the other international organisations such as the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), the Intergovernmental Panel on Climate Change (IPCC), as well as with non-government organisations such as the Wildlife Conservation Society (WCS) and the Consortium for Conservation Medicine. No single organisation can address the issues of climate change and environmental change and the impacts on emerging or re-emerging animal diseases and animal production. Partnerships and collaboration will be absolutely essential to build a more coherent view of the future landscape and to devise a range of strategic options about what might need to be done and how to do it.

Fortunately, these partnerships and collaborations are already being developed at the global level within the evolving 'one world, one health' framework that has support from institutions such as OIE, FAO, WHO, the UNSIC[1], UNICEF[2] and the World Bank. There are also a host of institutions involved at the regional level and these will all play a critical role in the development and delivery of the 'one health' approach [2].

Some of the challenges of working across disciplines and sectors have been recognised in this framework. For the OIE Members, it is worth noting that there are high transaction costs for collaboration and that cultural and perception issues need to be specifically addressed. In addition, there are barriers within institutions and bureaucracies that can be quite difficult to overcome. However, policy responses must recognise that the decisions that are made will directly affect the system that promotes or hinders the rate of emergence and spread of emerging and re-emerging animal diseases. The critical importance of real cooperation and collaboration at a range of levels should not be ignored.

Central Veterinary Authorities will naturally focus on the areas within their direct control such as surveillance and emergency response. This work could include more anticipatory activities so that surveillance and emergency response plans can be better targeted to cover some likely emerging and re-emerging animal disease threats while still being adaptable enough to deal with unexpected emerging and re-emerging animal diseases.

7. Questionnaire main findings

The questionnaire was sent to all 172 OIE Member Countries and Territories. Responses were received from 107, including 1 response from the European Union (EU) representing 27 countries. However, 7 of the 27 EU Members did respond individually and the following descriptive analysis includes each of these 7 responses separately and has counted each of the other 20 EU Member responses separately (basically replicating the EU response 20 times). This was done so that each Member was treated equally. Thus 126 responses were recorded from 172 Members, a response rate of 73%.

The list of responding Members is attached as Appendix I.

The level of concern of Central Veterinary Authorities in most Members about the likely impact on emerging and re-emerging animal diseases was either extreme or major for both climate change (71%) and environmental change (72%).

1 UNSIC: United Nations System for Influenza Coordination
2 UNICEF: United Nations Children's Fund

58% of Members identified at least one emerging or re-emerging animal disease that was believed to be directly associated with climate change and 30% identified at least one emerging or re-emerging animal disease believed to be directly associated with environmental change. More Members (24%) were unsure about whether an emerging or re-emerging animal disease was directly associated with environmental change compared to climate change (6%). The most frequently mentioned diseases are summarised in Table 1. Only a few OIE Members specifically mentioned diseases of aquatic animals. *Vibrio tubiashi* and *V. parahaemolyticus* in Pacific oysters and *Icthyophynos hoferi* in Pacific salmon and other fish species were mentioned in relation to climate change. Salmon infectious anaemia and crayfish plague were mentioned in relation to environmental change. The dominance of responses mentioning vector-borne diseases associated with climate change is consistent with the predicted impacts of climate change on emerging diseases of both animals and humans [8, 12] as previously discussed.

Most OIE Members indicated that the Central Veterinary Authority worked with other departments or agencies to address climate change (68%) and environmental change (71%) issues. In addition, 49% of Members had considered emerging and re-emerging animal disease issues related to more intensive animal production processes.

With respect to research capacity to address the impact of climate change and environmental change on animal diseases, 22% of Members indicated that they had no real research capacity. Of the 78% of Members with research capacity, university and government department research were the two most common research capacity elements reported.

Interestingly, 39% of Members did not believe —and a further 39% were not sure— that veterinary institutions are effectively preparing professionals who are capable of understanding the impact of climate change and environmental change on emerging and re-emerging animal diseases. There is clearly a need to address this lack of capacity in terms of training graduates and post-graduates with appropriate skills to deal with future challenges.

Virtually all (98%) responses indicated that the OIE should do more to assist Members to address the issues of the impacts of climate change and environmental change on emerging and re-emerging animal diseases and all activities were supported by at least 30% of responding Members. The four most frequently nominated activities, in descending order, were:

- designing a global strategy to assist Members to prevent/reduce effects of climate change and environmental change on animal disease and production;
- working with other international organisations that are directly involved in climate change and environmental change issues;
- communicating with Members; and
- monitoring and reviewing the effects of climate change on animal health.

The questionnaire also asked Members whether there was an opportunity for regional or sub-regional OIE activities to assist in addressing these impacts of climate change and environmental change on emerging and re-emerging animal diseases. Again, most Members (87%) indicated that there were opportunities; 11% was either unsure (8%) or did not believe (3%) that opportunities existed at the regional or sub-regional level. Many activities were listed by Members and quite commonly these were the same as the OIE activities at a higher level listed in the questionnaire. For example, many Members proposed holding workshops in the region to better prepare for the impacts of climatic and environmental change on emerging and re-emerging animal diseases and to improve communication networks to address these issues at the regional level. Actually, designing and delivering activities at the regional and sub-regional level is an appropriate response at the right scale when dealing with issues relating to climate change and environmental change. The impacts will be detected and experienced by Members and these will differ across the globe depending on regional influences.

Most Members (83%) indicated that they are keen to form *ad hoc* working or interest groups to address these issues. Indeed, almost 30% indicated a willingness to establish such groups immediately and another 63% would like to do so within one year.

8. Conclusions

The OIE will continue to play a critical role in assisting Members to obtain support to improve the ability of veterinary services to deal with emerging and re-emerging animal diseases. These challenges are global and require global leadership. In addition to this leadership role, the OIE has the opportunity to establish regional or sub-regional activities to assist in addressing these impacts of climate change and environmental

change on emerging and re-emerging animal diseases. The impacts will vary from region to region, so that addressing emerging and re-emerging animal diseases at the regional level will result in more targeted and robust strategies. The responses to the questionnaire show that most Members support this approach.

Most Members expect that the OIE will communicate with them about issues related to climate change, environmental change and emerging and re-emerging animal diseases. It is recommended that the OIE investigate mechanisms for effective communication about these issues.

Members indicated that the OIE could monitor and review the effects of climate change on animal health. In this context, the OIE could also assist Central Veterinary Authorities to develop decision-making frameworks that take into account new information about the evolving relationship between the ecosystem and emerging and re-emerging animal diseases. This approach allows the implementation of adaptive policy responses.

It is clear from the questionnaire that there is an opportunity for OIE to alert veterinary institutions to the need to prepare professionals who are capable of understanding the impact of climate change and environmental change on emerging and re-emerging animal diseases. This issue could be included in the forthcoming OIE conference that will discuss the quality of initial and continuing veterinary education curricula[1]. In addition, the OIE could highlight the importance of complex system concepts and developing adaptive policy responses.

Finally, the OIE should continue to collaborate and network with other institutions and agencies that are addressing the broader policy issues linked to climate change, environmental change and animal production. The OIE will continue to be the key player supporting the improvement of veterinary services in Member Countries and Territories as a major platform for dealing with emerging and re-emerging animal diseases. This role complements activities in many other agencies that also address issues related to emerging and re-emerging animal diseases and relationships with such agencies at the global and regional level need to be fostered. The evolving 'one world, one health' approach could be the vehicle for OIE to contribute —along with a range of other institutions— to a global strategy to reduce the effects of climatic and environmental changes on animal diseases and production.

References

[1] Alder M. (ed) (2008).– Changing environment; new perspectives. *Vet. Record*, **163**, 401.

[2] Anon. (2008).– Contributing to One World, One Health. A Strategic Framework for Reducing Risks of Infectious Diseases at the Animal-Human-Ecosystems Interface. Produced by FAO, OIE, WHO, UN System Influenza Coordination, UNICEF and the World Bank. (http://www.fao.org/docrep/011/aj137e/aj137e00.htm // Accessed on 22 January 2009).

[3] Black P.F., Murray J.G., Nunn M.J. (2008).– Managing animal disease risk in Australia: the impact of climate change. *Rev. sci. tech. Off. int. Epiz.*, **27** (2), 563-580.

[4] Das S.B., Joughin I., Behn M.D., Howat I.M., King M.A., Lizarralde D., Bhatia M.P. (2008).– Fracture propagation to the base of the Greenland ice sheet during supraglacial lake drainage. *Science,* **320**, 778-781.

[5] Daszak P., Cunningham A.A., Hyatt A.D. (2000).– Emerging infectious diseases of wildlife: threats to biodiversity and human health. *Science,* **287**, 443-449.

[6] De La Rocque S. (2008).– Introduction. *In:* Climate change: impact on the epidemiology and control of animal diseases. *Rev. sci. tech. Off. int. Epiz*., **27** (2), 303-304.

[7] De La Rocque S., Hendrickx G., Morand S. (eds) (2008).– Climate change: impact on the epidemiology and control of animal diseases. *Rev. sci. tech. Off. int. Epiz.,* **27** (2).

[8] De La Rocque S., Rioux J.A., Slingenbergh J. (2008).– Climate change: effects on animal disease systems and implications for surveillance and control. *Rev. sci. tech. Off. int. Epiz.,* **27** (2), 339-354.

[9] Eisenberg J.N.S., Desai M.A., Levy K., Bates S.J., Liang S., Naumoff K., Scott J.C. (2007).– Environmental determinants of infectious disease. A framework for tracking causal links and guiding public health research. *Environmental Health Perspectives*, **115** (8), 1216-1223.

[10] Folke C., Hahn T., Olsson P., Norberg J. (2005).– Adaptive governance of social-ecological systems. *Annu. Rev. Env. Resour*., **30**, 441-473.

[11] Hanson C., Ranganathan J., Iceland C., Finisdore J. (2008).– Guidelines for identifying business risks and opportunities arising from ecosystem change. Version 1.0. *The Corporate Ecosystems Services Review*. World Resources Institute. (http://pdf.wri.org/corporate_ecosystem_services_review.pdf // Accessed on 11 December 2008).

1 "Evolving Veterinary Education for a Safer World", Paris, France, 12-14 October 2009

[12] IOM (Institute of Medicine) (2008).– *Global climate change and extreme weather events: understanding the contributions to infectious disease emergence.* The National Academies Press, Washington, DC, USA. (http://www.nap.edu/catalog/12435.html // Accessed on 11 December 2008).

[13] IPCC (Intergovernmental Panel on Climate Change) (2007).– Summary for Policymakers. *In:* Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S., Qin D., Manning M., Chen Z., Marquis M., Averyt K.B., Tignor M., Miller H.L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. (http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html)

[14] Jones K.E., Patel N.G., Levy M.A., Storeygard A., Balk D., Gittleman J.L., Daszak P. (2008).– Global trends in emerging infectious diseases. *Nature*, **451**, 990-993.

[15] Joughin I., Das S.B., King M.A., Smith B.E., Howat I.M., Moon T. (2008).– Seasonal speedup along the western flank of the Greenland ice sheet. *Science,* **320**, 781-783.

[16] King L.J. (2004).– Emerging and re-emerging zoonotic diseases: challenges and opportunities. In: *Compendium of technical items presented to the International Committee or to Regional Commissions of the OIE, 2004*. OIE (World Organisation for Animal Health), 2005.

[17] Martens P., McMichael A.J. (eds) (2002).– *Environmental change, climate and health: issues and research methods*. Cambridge University Press.

[18] Mascarelli A.L. (2008).– What we've learned in 2008. *Nature Reports. Climate Change,* Vol. 3, January 2009. Macmillan Publishers Ltd. (http://www.nature.com/climate/2009/0901/pdf/climate.2008.142.pdf // Accessed on 22 January 2009).

[19] Mastepanov M., Sigsgaard C., Dlugokencky E.J., Houweling S., Ström L., Tamstorf M.P., Christensen T.R. (2008).– Large tundra methane burst during onset of freezing. *Nature,* **456**, 628-630.

[20] Millennium Ecosystem Assessment (2005).– Living beyond our means: natural assets and human well-being. (http://www.millenniumassessment.org/documents/document.429.aspx.pdf // Accessed on 11 December 2008).

[21] Nunn M., Black P. (2006).– Intensive animal production systems – How intensive is intensive enough? *In:* Proceedings of the 11th Symposium of the International Society for Veterinary Epidemiology and Economics, Cairns, Australia.

[22] Parkes M.W., Bienen L., Breilh J., Hsu L-N., McDonald M., Patz J.A., Rosenthal J.P., Sahani M., Sleigh A., Waltner-Toews D., Yassi A. (2005).– All hands on deck: transdisciplinary approaches to emerging infectious disease. *EcoHealth*, **2**, 258-272.

[23] Plowright R.K., Sokolow S.H., Gorman M.E., Daszak P., Foley J.E. (2008).– Causal inference in disease ecology: investigating ecological drivers of disease emergence. *Frontiers in Ecology and the Environment,* Vol. 6 No. 8, 420-429.

[24] Rosenzweig C., Karoly D., Vicarelli M., Neofotis P., Qigang W., Casassa G., Menzel A., Root T.L., Estrella N., Seguin B., Tryjanowski P., Chunzhen L., Rawlins S., Imeson A. (2008).– Attributing physical and biological impacts to anthropogenic climate change. *Nature*, **453**, 353-357.

[25] Smolinski M.S., Hamburg M.A., Lederberg J. (eds) (2003).– *Microbial threats to health: emergence, detection, and response.* Committee on Emerging Microbial Threats to Health in the 21st Century, Board on Global Health. The National Academies Press, Washington, DC, USA. (http://www.nap.edu/catalog.php?record_id=10636)

[26] Steinfeld H., Gerber P., Wassenaar T., Castel V., Rosales M., de Haan C. (2006).– *Livestock's long shadow: environmental issues and options*. Food and Agriculture Organization of the United Nations, Rome. (http://www.fao.org/docrep/010/a0701e/a0701e00.htm).

[27] Stern N. (2006).– Stern Review on the Economics of Climate Change. (http://www.hm-treasury.gov.uk/sternreview_index.htm // Accessed on 11 December 2008).

[28] Thompson L.G., Mosley-Thompson E., Brecher H., Davis M., León B., Les D., Lin P.N., Mashiotta T., Mountain K. (2006).– Abrupt tropical climate change: past and present. *PNAS*, **103** no. 28, 10536-10543. (http://www.pnas.org/content/103/28/10536.full.html // Accessed on 22 January 2009).

[29] Wilcox B.A., Colwell R.R. (2005).– Emerging and reemerging infectious diseases: biocomplexity as an interdisciplinary paradigm. *EcoHealth*, **2**, 244-257.

[30] OIE (World Organisation for Animal Health) (2008).– The new tool for the evaluation of performance of Veterinary Services (PVS Tool) using OIE international standards of quality and evaluation. (http://www.oie.int/eng/OIE/organisation/en_vet_eval_tool.htm // Accessed on 22 January 2009).

.../Appendix

Appendix I

OIE Members having responded to the questionnaire on "Impact of climate change and environmental changes on emerging and re-emerging animal disease and animal production"

1. Albania
2. Algeria
3. Angola
4. Argentina
5. Armenia
6. Australia
7. Azerbaijan
8. Bangladesh
9. Belarus
10. Belgium
11. Belize
12. Benin
13. Bolivia
14. Bosnia and Herzegovina
15. Botswana
16. Brazil
17. Brunei
18. Burkina Faso
19. Burundi
20. Canada
21. Central African Republic
22. Chile
23. People's Republic of China
24. Colombia
25. Democratic Republic of the Congo
26. Costa Rica
27. Côte d'Ivoire
28. Croatia
29. Cuba
30. Dominican Republic
31. El Salvador
32. Eritrea
33. Ethiopia
34. Gabon
35. Gambia
36. Georgia
37. Ghana
38. Greece
39. Guinea
40. Guinea Bissau
41. Haiti
42. Honduras
43. Iceland
44. India
45. Indonesia
46. Iran
47. Israel
48. Jamaica
49. Japan
50. Jordan
51. Kenya
52. Republic of Korea
53. Kuwait
54. Kyrgyzstan
55. Laos
56. Lesotho
57. Liechtenstein
58. Lithuania
59. Luxembourg
60. Madagascar
61. Malawi
62. Mali
63. Mauritius
64. Moldavia
65. Montenegro
66. Morocco
67. Myanmar
68. Namibia
69. Nepal
70. New Caledonia
71. New Zealand
72. Niger
73. Norway
74. Oman
75. Paraguay
76. Peru
77. Philippines
78. Portugal
79. Qatar
80. Romania
81. Rwanda
82. Senegal
83. Serbia
84. Singapore
85. South Africa
86. Spain
87. Sri Lanka
88. Sudan
89. Swaziland
90. Switzerland
91. Chinese Taipei
92. Tanzania
93. Thailand
94. Togo
95. Trinidad and Tobago
96. Tunisia
97. Turkey
98. Turkmenistan
99. United Arab Emirates
100. United States of America
101. Uruguay
102. Uzbekistan
103. Vanuatu
104. Vietnam
105. Zambia
106. Zimbabwe

and the European Union, representing the following countries:

107. Austria
108. Bulgaria
109. Cyprus
110. Czech Republic
111. Denmark
112. Estonia
113. Finland
114. France
115. Germany
116. Hungary
117. Ireland
118. Italy
119. Latvia
120. Malta
121. Netherlands
122. Poland
123. Slovakia
124. Slovenia
125. Sweden
126. United Kingdom