

Review of the Impact of Climate Change on Health in Rwanda

Appendix D

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A Review



Infectious diseases of humans continue to present a significant burden to our health. Infectious diseases of livestock affect their health and welfare, are themselves important causes of human disease and can threaten food security. These effects occur worldwide, but are disproportionately prevalent in the developing world. There are approximately two thousand known pathogens of humans; and several thousand pathogens of livestock (and a significant number shared between them; zoonoses). A large, but currently unknown, proportion is influenced by weather or climate. Given the number of pathogens and the evidence of strong links of many to climate, it seems unthinkable that a significant change in climate this century will not impact on at least some of them, possibly exposing human or animal populations to new disease risks.

These associations between weather/climate and pathogens, or the diseases they cause, fall broadly into four categories: where they occur (spatial, including latitudinal or altitudinal limits); when they occur (temporal, either within the year (seasonal) or in which years they occur (interannual)); and the size or severity of outbreaks (their intensity) [1].

How should we react to the risk posed by climate change to humans and animals in terms of effects on diseases? The answer depends on the animal populations or human communities affected, the nature and strength of the disease's response and, of course, the direction of change. Some diseases may spread but others may retreat in distribution or intensity. It also depends on the

relative importance of the disease. If climate change increases the burden of diseases that are existing major health issues, then we may face exacerbated, major health problems in future that severely test our health services. If, however, climate change mostly affects diseases of only minor importance, while more important infections are refractory to climate change's impacts, then our concerns should be tempered and our health services, especially in the developed world, may manage to take it in their stride.

The first step in producing a realistic assessment of the impact of climate change on human and animal health in Rwanda, therefore, is to ask what are the most important diseases in the country? The second is then to ascertain which, if any, of these important diseases have known associations with climate and might be expected, therefore, to be affected by climate change?

A survey of the major animal diseases of Rwanda was undertaken as follows: (i) data were extracted from a study that attempts to quantify the impact of different livestock diseases on poor people in the larger East African region [2]; (ii) examination of the Rwanda Animal Resources Development (RARDA) website (<http://www.rarda.gov.rw/>); (iii) extraction of all linkages between pathogens and livestock and Rwanda in PubMed.

Twenty-three livestock diseases identified as being of highest impact on poor people in East, Southern and Central Africa are summarised in Table 1. The listed diseases achieve high impact by scoring highly in terms of the economic

Table 1: Endemic diseases of East/Central/Southern Africa, with high impact on the poor (<http://www.ilri.cgiar.org/InfoServ/Webpub/fulldocs/investinginanimal/index.htm>)

| Disease | Livestock hosts | Important Zoonosis | Transmission route | Sensitive to climate |
|---|----------------------|--------------------|--|----------------------|
| Anthrax | All | Yes | Direct contact or exposure to spores | Yes |
| Babesiosis | Cattle | | Vectors (ticks) | Yes |
| Bovine tuberculosis | Cattle | Yes | Direct contact | Unlikely |
| Brucellosis | All | Yes | Direct contact | Unlikely |
| Botulism | All | Yes | Food / water | Unlikely |
| Coccidiosis | All | | Food / water | Unlikely |
| Contagious bovine pleuro-pneumonia (CBPP) | Cattle | | Direct contact | Unlikely |
| Cysticercosis | Cattle/pigs | Yes | Food/water | Unlikely |
| Dermatophilosis | Cattle, sheep, goats | | Direct contact | Unlikely |
| East coast fever (Theileriosis) | Cattle | | Vectors (ticks) | Yes |
| Ectoparasites | All | | Direct contact | Yes |
| Fasciolosis | Cattle, sheep | | Intermediate hosts (snails) | Yes |
| Foot-and-mouth disease (FMD) | Ruminants | | Direct contact / airborne | Unlikely |
| Fowl pox | Poultry | | Direct contact | Unlikely |
| Heartwater | Ruminants | | Vectors (ticks) | Yes |
| GI helminths | All | | Food/water | Unlikely |
| Haemonchosis | Cattle, sheep, goats | | Food/water | Yes |
| Infectious coryza | Poultry | | Food/water | Unlikely |
| Mange | All | Yes | Direct contact | Unlikely |
| Newcastle disease | Poultry | | Direct contact | Unlikely |
| Respiratory complexes | All | | Direct contact / airborne | Unlikely |
| Rift Valley fever | Cattle, sheep, goats | Yes | Vectors (mosquitoes); food-borne (to humans) | Yes |
| Trypanosomosis | Ruminants | Some | Vectors (tsetse flies) | Yes |

consequences of animal disease (a combination of prevalence, disease severity etc) or in terms of their zoonotic potential. The listed diseases affect all major species of livestock and, in many cases, wildlife. Eight are considered to be important zoonotic infections (a larger number is, technically, zoonotic) by [2]. They are transmitted by a variety of transmission routes, with most of the important

zoonoses however, being transmitted by direct contact or food/water.

A study to identify which pathogens of human and livestock have strong climate links (<http://www.liv.ac.uk/enhance/>) is ongoing but not yet complete. The sensitivities to climate in Table 1 reflect, therefore, the views of the authors. Nine diseases are identified as being sensitive to climate,

Table 2: Nature of the links to climate of climate-sensitive diseases identified in Table 1

| Disease | Nature of link to climate |
|-------------------|--|
| Anthrax | An acute infectious disease of most warm-blooded animals, including humans, with worldwide distribution. The causative bacterium, <i>Bacillus anthracis</i> , forms spores able to remain infective for 10-20 years in pasture. Temperature, relative humidity and soil moisture all affect the successful germination of anthrax spores, while heavy rainfall may stir up dormant spores. Outbreaks are often associated with alternating heavy rainfall and drought, and high temperatures [3]. |
| Babesiosis | A tick-borne protozoan disease of many mammals. Major tick vectors are species of <i>Boophilus</i> and <i>Rhipicephalus</i> . Survival of the tick vectors, and hence their presence/absence or abundance, is sensitive to rainfall and temperature. |
| Ectoparasites | Ectoparasites encompass a diverse range of arthropods (mites, ticks, lice, flies) which live on livestock. As above, their survival is sensitive to rainfall and temperature. |
| Fasciolosis | Fasciolosis, caused by the <i>Fasciola</i> trematode fluke, is of economic importance to livestock producers in many parts of the world and also causes disease in humans. In sheep, severe pathology, including sudden death, results from acute fasciolosis which occurs after ingestion of more than two thousand metacercariae (larval flukes) of <i>Fasciola hepatica</i> at pasture, while milder pathology associated with sub-acute and chronic fasciolosis occurs after ingestion of two hundred to one thousand metacercariae [4]. Acute fasciolosis is therefore most common in places or in years when rainfall and temperature favour the survival of large numbers of metacercariae [5]. In addition, the survival of the snail intermediate host is favoured by wetter, warmer climate. |
| Heartwater | A rickettsial disease of sheep, goats and cattle. The causative agent is <i>Cowdria ruminantium</i> . Major tick vectors are of the genus <i>Amblyomma</i> . Survival of the tick vectors, and hence their presence/absence or abundance, is sensitive to rainfall and temperature. |
| Haemonchosis | Caused by the nematode <i>Haemonchus contortus</i> , which occurs worldwide in the guts of sheep and cattle. It can cause significant economic loss in terms of reduced productivity or, with heavy infestations, mortality. Eggs are excreted in droppings. Survival of the eggs and larvae, until they are ingested by another animal, depends on temperature and moisture: under appropriate conditions of warmth and moderate humidity, the larvae can survive for weeks or months. [6] |
| Rift Valley fever | An important zoonotic viral disease of sheep and cattle, transmitted by <i>Aedes</i> and <i>Culex</i> mosquitoes. Epizootics of Rift Valley fever (RVF) are associated with periods of heavy rainfall and flooding [7-9] or, in East Africa, with the combination of heavy rainfall following drought associated with ENSO [8, 10]. ENSO-related floods in 1998, following drought in 1997, led to an epidemic of RVF (and some other diseases) in the Kenya/Somalia border area and the deaths of more than 2000 people and two-thirds of all small ruminant livestock [11]. |
| Trypanosomosis | Tsetse-transmitted trypanosomosis is one of the greatest disease constraints on livestock production in a large part of sub-Saharan Africa. The causative non-zoonotic protozoa (<i>Trypanosoma congolense</i> , <i>T. vivax</i> and <i>T. brucei brucei</i>) are transmitted to livestock by a large number of tsetse species with different environmental requirements; all, however, are highly sensitive to temperature and rainfall [12]. |

and hence possibly subject to effects of climate change. Of these, six are vector-borne or have snail intermediate hosts, reflecting the sensitivity of invertebrates to climate. Given the different transmission routes favouring zoonotic potential or sensitivity to climate, only three of the 23 diseases are classified as both: anthrax, Rift Valley fever and

trypanosomosis. It is important to note that Table 1 is based on approximately half of Africa and some of the diseases may not be present, or important, in Rwanda. This may be the case, for example, for the zoonotic forms of trypanosomosis (<http://www.who.int/mediacentre/factsheets/fs259/en/>).

Table 3: The 50 pathogens of highest H-index identified as being present in Rwanda by Pubmed. Pathogens that are vector-borne or have invertebrate intermediate hosts are in bold.

| Pathogen | H | Pathogen (continued) | H |
|--------------------------------|-----|--------------------------------|-----|
| human immunodeficiency virus 1 | 386 | neisseria gonorrhoeae | 132 |
| hepatitis c virus | 297 | mycobacterium bovis | 129 |
| salmonella | 260 | chlamydia trachomatis | 127 |
| staphylococcus aureus | 260 | neisseria meningitidis | 127 |
| hepatitis b virus | 241 | measles virus | 117 |
| human papillomavirus | 236 | aeromonas | 111 |
| pseudomonas aeruginosa | 232 | streptococcus pyogenes | 111 |
| mycobacterium tuberculosis | 228 | lentivirus | 104 |
| cytomegalovirus | 226 | entamoeba histolytica | 97 |
| bacillus subtilis | 211 | ascaris | 87 |
| campylobacter | 203 | treponema pallidum | 86 |
| plasmodium falciparum | 202 | trichomonas vaginalis | 86 |
| streptococcus pneumoniae | 192 | shigella dysenteriae | 79 |
| escherichia coli | 180 | mycobacterium smegmatis | 78 |
| candida albicans | 174 | mycobacterium fortuitum | 59 |
| human t-lymphotropic virus 1 | 148 | trypanosoma brucei brucei | 59 |
| pneumocystis carinii | 146 | haemophilus ducreyi | 56 |
| haemophilus influenzae | 145 | theileria parva | 54 |
| toxoplasma gondii | 144 | frankia | 52 |
| borrelia | 142 | shigella sonnei | 51 |
| klebsiella pneumoniae | 141 | nocardia asteroides | 50 |
| vibrio cholerae | 140 | trichuris trichiura | 49 |
| shigella flexneri | 139 | trichophyton rubrum | 46 |
| schistosoma mansoni | 136 | trypanosoma brucei rhodesiense | 44 |
| rotavirus | 134 | microsporium | 42 |

Information specific to Rwanda was obtained from the RARDA website. The main livestock diseases were bovine tuberculosis, brucellosis, CBPP, FMD, GI helminths, ticks (as ectoparasites), tick-borne diseases and trypanosomiasis. All of these diseases are contained in Table 1.

To better gauge how climate change in Rwanda may affect these diseases, it is valuable to consider how they are linked to climate today. Table 2 is not exhaustive, but gives some indication of the nature of the climate links of the eight climate-sensitive livestock diseases identified so far in Rwanda.

A detailed assessment of the possible impact of climate change on human health in Rwanda is beyond the scope of this study. However, a brief survey is included here. The Enhanced Infectious Disease (EID) database (<http://www.liv.ac.uk/enhance/news/index.htm>) was mined for evidence of links between pathogens and humans in Rwanda. It identified 74 pathogens in the country (i.e. papers were identified naming 74 different human pathogens and the country name, Rwanda, as a MeSH term). These pathogens range from those of high impact on humans to those of negligible importance. Here, therefore, they have been filtered for those of higher global impact using a newly developed tool for disease prioritisation, the H-index^[13].

The fifty pathogens of highest H-index, identified by PubMed as present in Rwanda, are shown in Table 3. The list is likely to be imperfect as an estimate of the true health challenges of Rwanda, containing some false positives (ie, pathogens falsely given a high H index with respect to their impact in Rwanda); and excluding some false negatives (pathogens that are locally, but not globally important). Nevertheless, the picture it presents is hopefully still useful.

The listed pathogens are transmitted to people by many different routes, mainly sexual, food-borne, water-borne, respiratory or by direct contact. Some of these non-vector borne pathogens may be sensitive to climate and, hence, susceptible to climate change. A good example is cholera, a diarrhoeal disease which has killed tens of millions

of people worldwide, caused by the bacterium *Vibrio cholerae*, which lives amongst sea plankton [14]. High temperatures causing an increase in algal populations often precede cholera outbreaks. Disruption to normal rainfall helps cholera to spread further, either by flooding, leading to the contamination of water sources, such as wells, or drought which can make the use of such water sources unavoidable. Contaminated water sources then become an important source of infection in people. There are also links between climate and certain food-borne diseases such as salmonellosis [15]. Salmonellosis is a serious food-borne disease caused by *Salmonella* bacteria, most often obtained from eggs, poultry and pork. Salmonellosis notification rates in several countries have been shown to increase by about 5-10% for each 1 °C increase in ambient temperature. Salmonellosis notification is particularly associated with high temperatures during the week prior to consumption of infected produce, implicating a mechanistic effect via poor food-handling.

While some non-vector-borne diseases are climate-sensitive, it remains the case that examples are few and far between. It is important to note, therefore, that only seven of the 50 pathogens are vector-borne. The most important is the mosquito-borne *Plasmodium falciparum*, the cause of malaria. *Borrelia* is the tick-borne cause of certain relapsing fevers present in parts of Rwanda. *Schistosoma mansoni* is the parasite that causes bilharzia or schistosomiasis. Schistosomiasis is an important cause of human mortality and morbidity in Africa and, to a lesser extent, in Asia. The parasite requires water-living snails as intermediate hosts and therefore its distribution depends on the existence of suitable water bodies; year-round warm temperatures are also required for survival of the parasite. *Trypanosoma brucei brucei* and *T. b. rhodesiense* cause trypanosomiasis and sleeping sickness in livestock and humans respectively, and have been discussed earlier. *Theileria parvi* is the tick-borne causative agent of East coast fever.

Climate change might be expected to impact on a number of these diseases in Rwanda, most notably permitting them to occur at higher altitudes

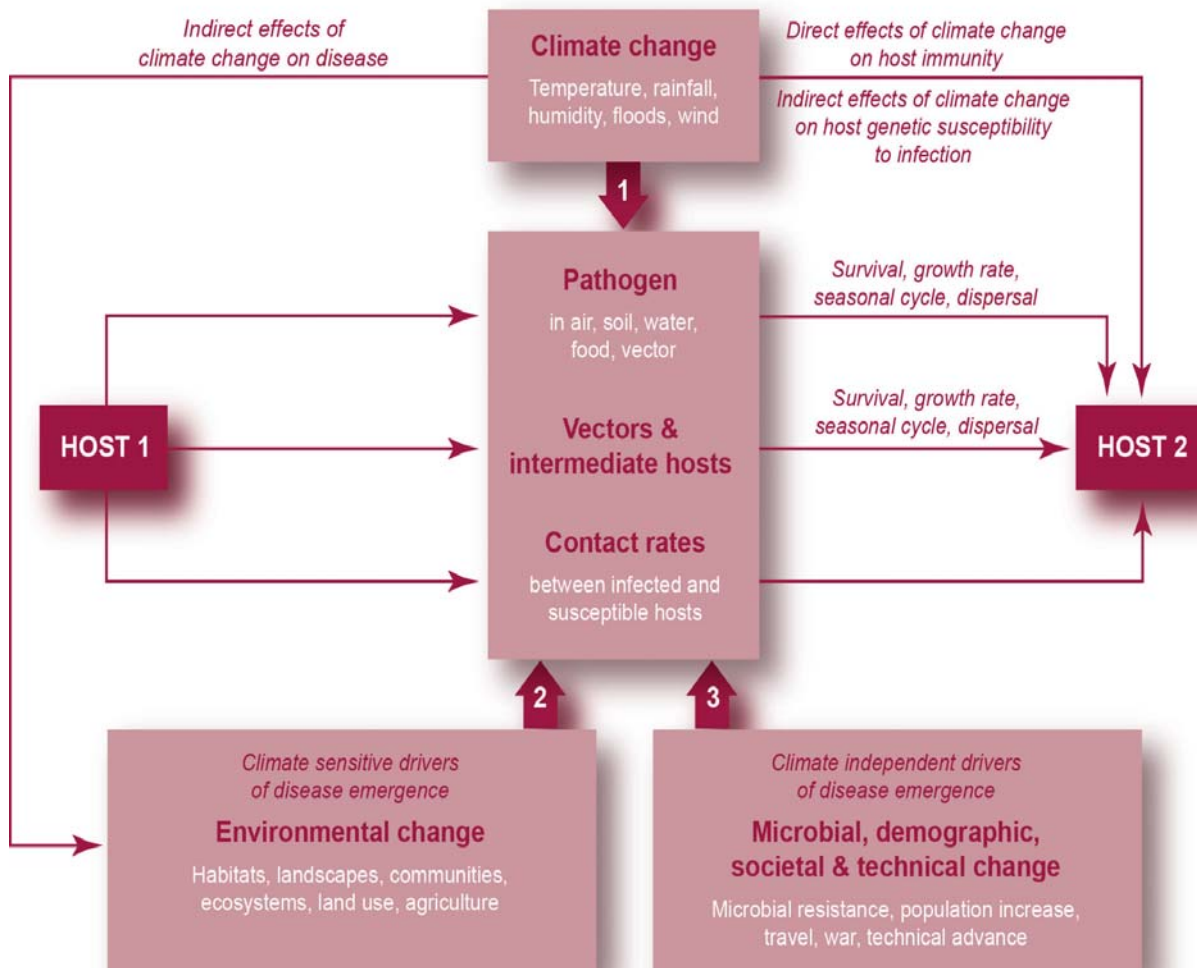


Figure 1: A schematic framework of the effects of climate change on the transmission of diseases of humans and animals. Climate change can act directly on pathogens in a range of external substrates, or their vectors and intermediate hosts, thereby affecting the processes of survival, growth, seasonality and dispersal. It can also directly affect hosts themselves or the contact rates between infected and susceptible individuals. Climate change can have indirect effects on disease transmission via its effects on the natural or anthropogenic environment; and via the genetics of exposed populations. Environmental, demographic, social and technical change will also happen independently of climate change and have as great, or much greater influence on disease transmission than climate change itself. The significance of climate change as a driver of disease will depend on the scale of arrow 1, and on the relative scales of arrows 2 and 3.

(as described for malaria by Bouma & Kovats elsewhere in the report). However, it is worth noting that for humans, the majority of the high-impact pathogens present in Rwanda are unlikely to have significant links to climate and, therefore, are

unlikely to be susceptible to effects of climate change.

It may be noteworthy that 7 out of 50 (14%) high-impact human pathogens are vector-borne, compared to 9 out of 23 (40%) of animal diseases.

This may reflect the different sampling strategies employed here but, probably, also reflects the different lifestyles of humans and animals: in essence, animals are more exposed to, and less able to defend themselves from, the attacks of arthropod pests. Given the strong, established links between vector-borne diseases and climate, this may suggest that animal health will be more affected by climate change than human health.

Finally, it is imperative to consider the effects of climate change on health in the context of other health drivers which may change over similar or shorter time scales. Even if climate change is expected to affect an important disease, its occurrence may be more susceptible to change in other drivers such that, over decadal time scales, the overall impact of climate change is relatively minor. A framework presenting the impact of climate change on diseases, in the context of other drivers, is shown in Figure 1.

The need to consider climate change in the context of other disease drivers is made clear by a comparison of malaria and bluetongue in the late 20th century. Both diseases are spread by vectors

(mosquitoes and midges, respectively); and the vectors and the pathogens within them are affected in near identical ways by climate. Naively, both might be expected to be influenced in similar ways and to similar extents by recent climate change. However, their stories are very different: bluetongue, a viral disease of ruminant livestock, has emerged dramatically in Europe because of climate change^[16]; but malaria, a protozoan disease of humans, has decreased dramatically in incidence, worldwide^[17]. The reason for the difference is as follows: bluetongue, a disease of hitherto minor importance, even for livestock, attracted little research and little advancement in control methodologies in the last 50 years such that climate change's influence on the disease was able to be realised into dramatic effect, killing millions of European sheep and cattle in the last decade. By contrast, for malaria changes in drivers other than climate, such as land use and housing, the availability of new therapies, insecticides and, nowadays, insecticide-treated bed-nets, have played far more dominant roles in reducing malaria occurrence than climate change may have played in increasing it.

References



[1] Baylis M, Githeko AK (2006) State of Science review: The effects of climate change on infectious diseases of animals. Office of Science and Innovation, London

[2] Perry BD, Randolph TF, McDermott JJ, Sones KR, Thornton PK (2002) Investing in Animal Health Research to Alleviate Poverty. International Livestock Research Institute, Nairobi, Kenya

[3] Parker R, Mathis C, Looper M, Sawyer J (2002) Guide B-120: Anthrax and livestock. Cooperative Extension Service, College of Agriculture and Home Economics, University of New Mexico, Las Cruces, New Mexico

[4] Behm CA, Sangster NC (1999) Pathology, Pathophysiology and Clinical Aspects. In: Dalton JP (ed) Fasciolosis. CAB International, Wallingford, Oxon, pp 185-224

[5] McCann CM, Baylis M, Williams DJL (2010) The development of linear regression models using environmental variables to explain the spatial distribution of *Fasciola hepatica* infection in dairy herds in England and Wales. *Int J Parasitol* 40: 1021-8

[6] van Dijk J, David GP, Baird G, Morgan ER (2008) Back to the future: Developing hypotheses on the effects of climate change on ovine parasitic gastroenteritis from historical data. *Veterinary Parasitology* 158: 73-84

[7] Davies F, Linthicum K, James A (1985) Rainfall and epizootic Rift Valley fever. *Bull World Health Org* 63: 941-3

[8] Linthicum KJ, Anyamba A, Tucker CJ, Kelley PW, Myers MF, Peters CJ (1999) Climate and

[1] Baylis M, Githeko AK (2006) State of Science review: The effects of climate change on infectious diseases of animals. Office of Science and Innovation, London

[2] Perry BD, Randolph TF, McDermott JJ, Sones KR, Thornton PK (2002) Investing in Animal Health Research to Alleviate Poverty. International Livestock Research Institute, Nairobi, Kenya

[3] Parker R, Mathis C, Looper M, Sawyer J (2002) Guide B-120: Anthrax and livestock. Cooperative Extension Service, College of Agriculture and Home Economics, University of New Mexico, Las Cruces, New Mexico

[4] Behm CA, Sangster NC (1999) Pathology, Pathophysiology and Clinical Aspects. In: Dalton JP (ed) Fasciolosis. CAB International, Wallingford, Oxon, pp 185-224

[5] McCann CM, Baylis M, Williams DJL (2010) The development of linear regression models using environmental variables to explain the spatial distribution of *Fasciola hepatica* infection in dairy herds in England and Wales. *Int J Parasitol* 40: 1021-8

[6] van Dijk J, David GP, Baird G, Morgan ER (2008) Back to the future: Developing hypotheses on the effects of climate change on ovine parasitic gastroenteritis from historical data. *Veterinary Parasitology* 158: 73-84

[7] Davies F, Linthicum K, James A (1985) Rainfall and epizootic Rift Valley fever. *Bull World Health Org* 63: 941-3

- [8] Linthicum KJ, Anyamba A, Tucker CJ, Kelley PW, Myers MF, Peters CJ (1999) Climate and satellite indicators to forecast Rift Valley fever epidemics in Kenya. *Science* 285: 397-400
- [9] Linthicum KJ, Bailey CL, Davies FG, Tucker CJ (1987) Detection of Rift Valley fever viral activity in Kenya by satellite remote sensing imagery. *Science* 235: 1656-9
- [10] Anyamba A, Linthicum KJ, Mahoney R, Tucker CJ, Kelley PW (2002) Mapping potential risk of Rift Valley fever outbreaks in African savannas using vegetation index time series data. *Photogramm Eng Remote Sens* 68: 137-45
- [11] Little PD, Mahmoud H, Coppock DL (2001) When deserts flood: risk management and climatic processes among East African pastoralists. *Clim Res* 19: 149-59
- [12] Rogers DJ, Packer MJ (1993) Vector-borne diseases, models, and global change. *Lancet* 342: 1282-4
- [13] McIntyre K, Hawkes I, Waret-Szkuta A, Morand S, Baylis M (2011) The H-Index as a Quantitative Indicator of the Relative Impact of Human Diseases. *PLoS ONE* 6: e19558
- [14] Eiler A, Johansson M, Bertilsson S (2006) Environmental influences on *Vibrio* populations in northern temperate and boreal coastal waters (Baltic and Skagerrak Seas). *Appl Environ Microbiol* 72: 6004-11
- [15] Kovats RS, Edwards SJ, Hajat S, Armstrong BG, Ebi KL, Menne B (2004) The effect of temperature on food poisoning: a time-series analysis of salmonellosis in ten European countries. *Epidemiol Infect* 132: 443-53
- [16] Guis H, Caminade C, Calvete C, Morse A, Tran A, Baylis M (2011) Modelling the effects of past and future climate on the risk of bluetongue emergence in Europe. *J Roy Soc Interface* in press
- [17] Gething PW, Smith DL, Patil AP, Tatem AJ, Snow RW, Hay SI (2010) Climate change and the global malaria recession. *Nature* 465: 342-4