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Climate change – Is it paving the way for the expansion of CVBD?

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Bayer Parasite Solutions

Introduction

When Bayer Animal Health called for the 1st International CVBD Symposium in 2006, it was the first and initial step to addressing the global threat of canine vector-borne diseases (CVBD). This was based on the belief that canine vector-borne diseases should be treated as one topic and dealt with on a global level and in an interdisciplinary way. During the past years, CVBD have become a global issue and even sparked public interest. Many of the parasite-transmitted diseases affect humans as well as animals. As man's best friend, dogs play an important role as they are affected to a high extent by zoonotic pathogens, even serving as a host for some of them.

At the first symposium, the participants agreed to form the CVBD World Forum. Besides gathering knowledge, the main task of this group of international experts has been to raise awareness for the specific regional risks of CVBD and to foster preventative measures. For this reason, the CVBD World Forum created a website (www.cvbd.org) to provide the veterinary practitioners with cutting-edge and clinically relevant scientific information on CVBD.

In the CVBD Digest, relevant findings from CVBD symposia are presented periodically to veterinary practitioners around the globe. During the three symposia so far, the impact of climate change on CVBD has been an important issue. While global warming is more or less accepted as a fact by both experts and the public, the effect on parasites and their transmitted diseases is still the subject of heavy debate. There is also a local component of climate change that strongly influences the regional situation of CVBD. Moreover, veterinarians should consider other man-made factors such as pet travel, mobility or import – all of which could raise the CVBD threat for dogs in many, if not most parts of the world.

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Climate change – Does it pave the way for an expansion of CVBD?

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Parasite-transmitted diseases are one of the major contributors to the global burden of disease in humans and animals. Climate change is often held responsible for the spread of parasitic vectors such as ticks, fleas, mosquitoes and sand flies, and their transmitted pathogens – leading, in the case of the dog, to so-called canine vector-borne diseases (CVBD). Currently, there is insufficient data available to prove if climate change is a major driving force for vector and disease expansion. Other reasons, such as ecological, demographic and socio-economic factors e.g. pet travel into and pet import from endemic areas, also play a role in this development. Whatever the reasons might be for possible disease expansion, prevention has to be focused on educating dog owners who are responsible for individual parasite protection as well as for risk-adverse behaviour, e.g. regarding pet travel. Broad-spectrum vector control should be practiced by using parasiticides that repel and kill blood feeders in order to minimize the risk of CVBD-pathogen transmission.

Climate change and vector-borne diseases

Climate change is defined as a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period of time. Meanwhile there is good evidence that climate is changing. The global average land and sea surface temperature has increased by 0.6 ± 0.2 °C since the mid-19th century.[1] Furthermore, the Intergovernmental Panel of Climate Change (IPCC) 4th Assessment Report states that "most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations, and that it is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica)".[2] For the future, this process might even be accelerated (Fig1). However, besides global climate changes, regional and local climate development as well as microclimate changes have to be considered, especially, since they are also of major importance for vector-borne disease development (see below).

An increasing number of studies and publications try to determine whether, and how, climate change is affecting vector-borne diseases. Most intermediate hosts and vectors and the majority of reservoirs have well defined geographic distributions resulting from evolutionary processes that condition the disease they transmit or shelter. Within its area of distribution, each species finds more or less suitable conditions for its development and multiplication and thus for disease transmission. Any events that modify the climate or environment affect the epidemiology of a disease.[3] Global climate change might expand the distribution of vector-borne pathogens in both time and space, thereby exposing host populations to longer transmission seasons, and immunologically naïve populations to newly introduced pathogens.[4] However, caution is necessary when interpreting these predictions.

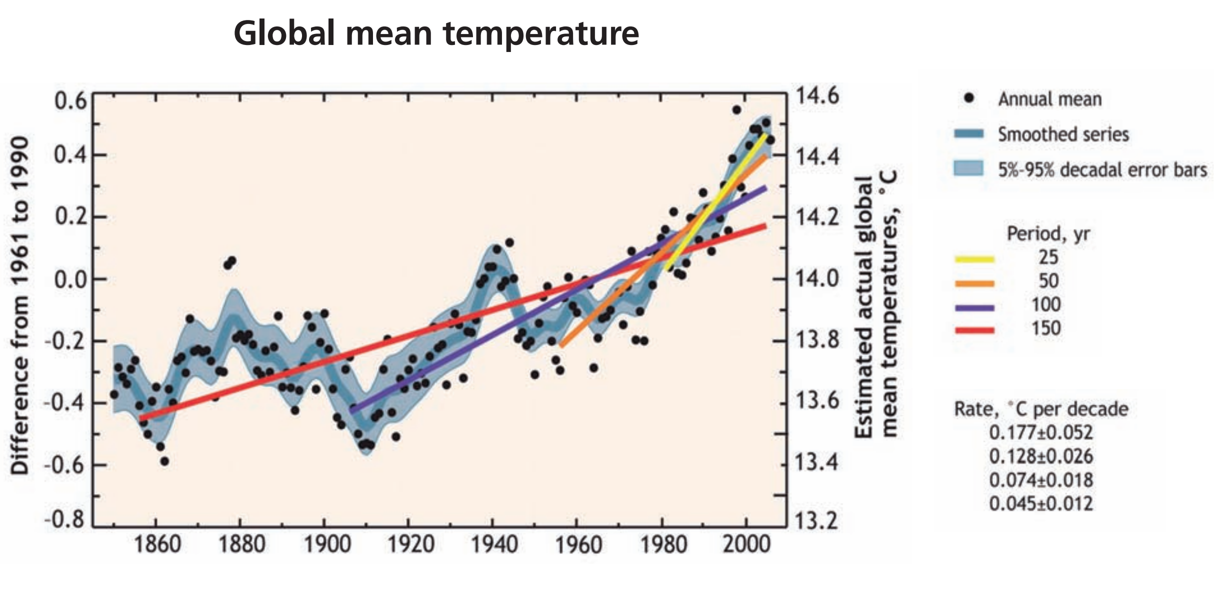

Fig. 1: Trends in mean global temperatures since the mid-19th-century. Coloured lines represent the linear trends over various time periods. As the lines become progressively shorter, the corresponding slopes steepen - indicating an accelerating warming trend for the world (reproduced, with permission from reference 2).

With respect to disease transmission, changes in the following properties are considered to be most important: (i) survival and reproduction rates of vectors, in turn determining their distribution and abundance; (ii) intensity and temporal pattern of vector activity (particularly biting rates) throughout the year; and (iii) rates of development, survival and reproduction of pathogens within vectors.[5] Additionally, the ability of disease-transmitting vectors to react to climate changes via active or passive dispersal also has to be considered (Tab. 1).

The role of temperature

The surrounding temperature directly influences the physiology of the cold-blooded vectors and the pathogens they submit. In many cases the pathogen only develops within the vector (outer incubation) within a certain temperature range, even though both may tolerate more extreme temperatures. For example, development of the so-called heartworm *Dirofilaria immitis* in its mosquito host needs an average temperature of at least 18 °C over a 30-day period (see also Info box 1). Below 18 °C larval development is retarded, but partial development still occurs. The lower threshold temperature, below which larval development does not take place, is

INFO BOX 1

HEARTWORM DISEASE IN THE UK?

Studies have shown that summer temperatures in certain parts of the UK and during particular years can facilitate the incubation of *Dirofilaria immitis* larvae in the mosquito intermediate host[25], with transmission being dependent on the presence of sufficient numbers of susceptible mosquitoes and a large enough population of infected dogs. It is suggested in turn that summer conditions as described above may occur in three out of five summers by 2080 in the UK.[26]

Vector	Major disease	Active dispersal	Passive dispersal
Ixodes ticks	Lyme borreliosis, tick-borne encephalitis	very limited powers of active dispersal	common and wide ranging, due to long periods of feeding: attachment to birds and large mammals
Mosquitoes	malaria, (diro)filariosis, dengue fever, yellow fever, West Nile fever (WNF)	able to disperse and reproduce relatively rapidly to exploit newly suitable areas	common and wide ranging: often transported by human transportation, including inter-continental air crafts and cargo
Sand flies	leishmaniosis	limited flight ranges	highly unlikely
Fleas	bartonellosis	limited dispersal, inbetween couple of centimeters as emerging adults	common and wide ranging, due to infestation of mammals

Tab. 1: Potential vector responses to climate change (modified after reference 5)

	Mosquito	Pathogen
transmission increased due to	abbreviated developmental time of larvae and pupae abbreviated gonotropic cycle more frequent oviposition increased biting frequency	faster replication abbreviated outer incubation time (pathogen within the vector)
transmission reduced due to	abbreviated life time	

Tab. 2: Effects of temperature increase on vector (i.e. mosquito), pathogen and frequency of transmission[24]

generally agreed to be 14°C for *D. immitis*[6,7,8,9] (see also Info box 1).

For the protozoan *Leishmania* sp. a minimum of 10°C is necessary to initiate the invertebrate cycle, and the rising temperature is continuously shortening the time needed for completion, which is at least 6 days for *Leishmania infantum*.[10,11] The 10°C year isotherm is furthermore limiting the occurrence of the *Leishmania* vector *Phlebotomus* sp. During recent years, *Phlebotomus* sand flies have been known to expand e.g. to northern regions in Italy[12]. Thus, both vector and pathogen might be influenced in their geographical distribution by rising temperatures.

In general, higher temperatures usually abbreviate the development time of the outer incubation of the pathogen, but also abbreviate the survival time of the vector with oppositional effect on the frequency of transmission.[13] The effects of the temperature rise are considered to cause an increase of the pathogen transmission rate in the first place (Tab. 2). For ticks, both the delay period and mortality vary geographically and seasonally with climate. While tick birth and development rates increase with temperature, tick mortality rates increase with moisture stress.[14]

Microclimate affecting ticks

Climate change might not only have a distinct effect on the development cycle of a vector. Through changing precipitation and even seasons, climate change also alters the microclimate as well as tick biology and feeding behaviour.

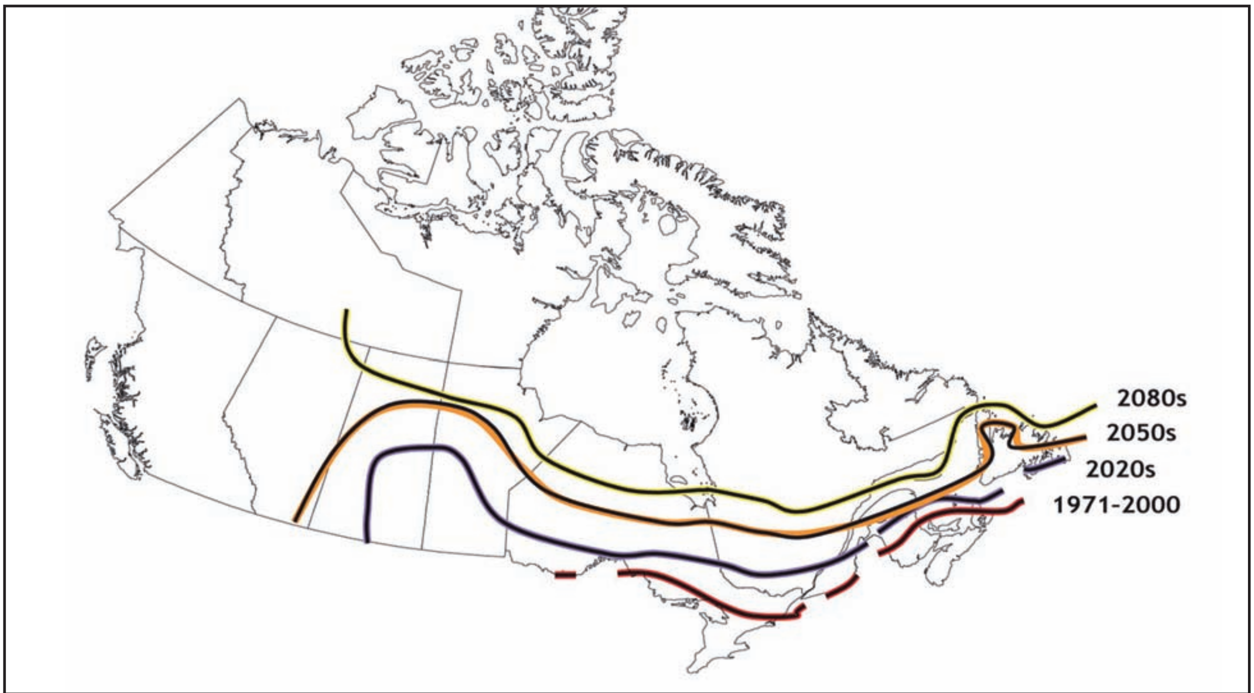

Fig. 2: Upper temperature limits for Deer tick *Ixodes scapularis* establishment in Canada, based on mathematical models. The graph shows the current upper geographic limits (brown) and the projected limits for the 2020s (blue), 2050s (orange) and 2080s (yellow), assuming continuous population growth, regionally oriented economic development, and no reduction in greenhouse gas emissions. (With permission from reference 36 – modified from reference 20)

Ixodes ticks, for example, are very susceptible to desiccation while questing for hosts in the vegetation. For passive and active atmospheric water uptake, they periodically return to moist conditions at the base of the vegetation to restore their fluid content.[15,16,17,18] It has been observed that under increasingly dry conditions the numbers of unfed nymphal *Ixodes ricinus* questing in upper layers of the herbage decreased, whereas the rate of fat use and the number of nymphs feeding on small rodents both increased. For *Ixodes* larvae, very few larvae quested or fed on rodents in dry conditions, but many more did so once the humidity increased, suggesting that larvae escape desiccation by becoming quiescent. The ratio of larvae to nymphs feeding on rodents thus increased with rising humidity, contributing to the seasonal and geographical variation in disease transmission dynamics.[19] Nevertheless, the authors admit that the behaviour described above may be different in ticks from different regions which might be adapted and acclimatized to their particular microclimate.

Despite this possible influence of climate on ticks, changing climatic factors that explain both the spatial variation and the temporal patterns in tick-borne disease 'emergence' have not yet been identified in detail. Retrospective climate evaluation in the UK e.g. did not reveal obvious differences between sites where human tick-borne encephalitis (TBE), as one of the best studied tick-borne diseases, did or did not 'emerge'.[14] But field studies by Ogden and colleagues[20] in Canada at least supported temperature and tick immigration based risk maps (Fig. 2) for the mere northward expansion of *Ixodes scapularis* (see also Info box 2).

Impact of other factors

The ecology and epidemiology of vector-borne diseases are affected by the interrelations between four major factors comprising the pathogen, the host (human or animal), the vector and the environment. Besides atmospheric and climatic changes,

INFO BOX 2

SUGGESTED SPREAD OF THE DEER TICK IN CANADA

Studies using a population model based on temperatures which are projected for the next decades by two climate models for two greenhouse gas emission scenarios suggest a northward expansion of the Black-legged or Deer tick *I. scapularis* by approximately 200 km by the 2020s and 1,000 km by the 2080s far into Canada in the case of one of these emission scenarios. Besides this northward expansion, further calculations also expect tick abundance to have almost doubled by the 2020s at the current northern limit of *I. scapularis*, suggesting that lower numbers of immigrating ticks are needed to establish new stable populations in coming decades.[28] A northward expansion of Lyme disease agent through the Black-legged tick may also occur. This Lyme disease prognosis has been partially confirmed by risk algorithm for *I. scapularis* population occurrence and a field study.[20]

alternative 'background' socio-economic, demographic and ecological effects (see also Info boxes 3 and 4) are plausible enough to cast some doubt on the role of climate change.[21]

INFO BOX 3

IMPORTANT DRIVERS FOR VECTOR-BORNE PARASITE EMERGENCE AND SPREAD[29]

- habitat changes
- alterations in water storage and irrigation habits
- pollution
- development of insecticide and drug resistance (e.g. *Anopheles* sp. and DDT)
- globalization
- increase in international trade, tourism and travel
- immunodeficient hosts (e.g. HIV infection in humans)
- war and civil unrest
- global and governmental management failure

Some of these effects facilitating a spread of vectors and pathogens are illustrated in more detail below:

(i) extended outdoor activities leading to higher exposures, either by an increase in leisure time (increased living standard) or by an increase in outdoor work and use of natural resources (decreased living standard);

(ii) altered farming conditions, increased scrubland, urbanization with poor hygienic measures;

(iii) increased (pet) travel, increased pet import into non-endemic regions

Urbanization (ii) as one of the main risk factors has e.g. been reported for zoonotic cutaneous and visceral leishmaniosis (ZCL, ZVL) in the New World (see also Info box 5).

In the case of pet travel and the import of dogs from endemic areas (iii) the spread of heartworm disease in the dog population of North America is a well described example (see also Info box 6). For Europe, 20,000 imported *Leishmania*-infected dogs are estimated to be living in Germany. These could act as a reservoir if the appropriate *Phlebotomus* species became endemic in this country or if the autochthonous species *P. mascitii* is a capable vector (see also Info box 6).

INFO BOX 4

WEST NILE FEVER IN THE US

West Nile fever (WNF) is enzootic in the hibernation areas of migratory birds in Africa and the southern states of the USA. Epidemics in the USA are correlated with a combination of warm winters and dry, hot summers.[30] The temperatures promote a hibernation of the vector and accelerate the outer incubation of the virus within the vector. The aridity e.g. promotes the multiplication of the urban WNF mosquito vector *Culex pipiens*, which breeds under the surface in drainage pits or underground funnels and which favours contaminated water. Rain floods these breeding places and the larvae are washed away.[30] However, the geographical spread of WNF in more than 40 US states since 1999 is less related with possible climate changes but rather with the accidental introduction of the virus and subsequent establishment of a new natural focus in the hibernation areas of migratory birds.[31]

INFO BOX 5

URBANIZATION AS A DRIVER OF LEISHMANIOSIS IN SOUTH AMERICA

The main risk factors of zoonotic cutaneous leishmaniosis (ZCL) in Latin America are: urbanization of respectively new settlements, deforestation/agricultural development and subsequently the domestication of the transmission cycle.[32] For example in Manaus, Brazil, the planned and unplanned construction of new suburbs on the outskirts of the primary forest brought many people into contact with the zoonotic cycle of *Leishmania* sp. A correlation between the risk of transmission to humans and the proximity of the forest has clearly been established.[33] Furthermore, unprecedented widespread deforestation has frequently led to a domestication of transmission throughout Latin America instead of reducing ZCL incidence.[32] Concerning zoonotic visceral leishmaniosis (ZVL), migration from rural to urban areas (with settlements in the shanty towns of the main cities) as occurring in north-eastern Brazil is regarded as one of the main risk factors. In these poor suburbs, the sand fly vector is everywhere, dogs are very common, sanitary conditions are poor and malnutrition is a significant risk factor, resulting in the increasing spread of ZVL among the population.[32] This phenomenon of urbanization of ZVL has also been reported from Colombia and Venezuela.[34]

INFO BOX 6

HEARTWORM DISEASE IN THE US

A confirmed example of disease spread due to pet travel is represented by the expansion of heartworm disease over the last 50 years with believed autochthonous transmission in all 49 states of the US in North America and most of the Canadian provinces.[35] For probably 450 years, the disease was restricted to the south-eastern coastal United States, before the transport of southern dogs for hunting and breeding and the movement of dogs belonging to army personnel introduced the disease in the other US states.

Conclusion

Undoubtedly, changing climatic conditions and their alterations in temperature and humidity do have an influence on disease-transmitting vectors and their surrounding microclimate. However, the availability of hosts is a major limiting factor for the spread of vector and pathogen.

Although biological reasons seemingly support the theory that anticipated climate change will cause a spread of vector-borne diseases, ecological and socio-economic factors have in the past proven to be stronger driving forces for the spread of infectious diseases than climate.[13] At a continental scale, climate may be a good predictor of disease distribution (e.g. Lyme disease in the USA[22]), but on the 'local scale' other environmental factors are likely to be more important.[5] To prove the individual effect of each factor, more data, new approaches and intensive studying are necessary. A step into that direction is disease distribution mapping with the help of remote sensing and GIS technology. Long term data over decades in extended areas are needed. The often missing strong evidence of climate change on vector-borne diseases has to be seen as an 'absence of evidence', rather than an 'evidence of absence', as stated by Kovats and colleagues.[5]

Transmission of clinically important canine vector-borne organisms to new regions, either due to climatic factors or due to dog travel and import, is of particular concern to veterinary clinicians, as the diseases caused by these organisms might be unfamiliar to them and may go undiagnosed.[23] Therefore, when it comes to disease prevention, education of the dog owner regarding individual parasite protection and risk-adverse behaviour is still the method of choice. Broad-spectrum ectoparasiticides on the basis e.g. of a monthly spot-on application can protect against ticks, fleas, sand flies, mosquitoes and stable flies. If these remedies als provide a repellent effect, they will further reduc- the risk of CVBD-pathogen transmission via the aforementioned vectors which can cause dangerous diseases in dogs. Such preventative measures should be frequently applied in endemic areas to control a disease as well as in dogs which are brought there from non-endemic regions.

References

1. Intergovernmental Panel on Climate Change (IPCC) (2001): Climate change 2001: The scientific basis. Summary for policymakers. Cambridge University Press, Cambridge, UK, 1–20
2. Intergovernmental Panel on Climate Change (IPCC) (2007): Climate change 2007: Synthesis report. Summary for policymakers. Cambridge University Press, Cambridge, UK, 1–22
3. Mouchet, J., Carnevale, P. (1997): [Impact of changes in the environment on vector-transmitted diseases.] Sante 7, 263–269
4. Patz, J.A., Reisen, W.K. (2001): Immunology, climate change and vector-borne diseases. Trends Immunol. 22, 171–172
5. Kovats, R.S., Campbell-Lendrum, D.H., McMichael, A.J., Woodward, A., Cox, J.S. (2001): Early effects of climate change: do they include changes in vector-borne disease? Philos. Trans. R. Soc. Lond. B Biol. Sci. 356, 1057–1068
6. Genchi, C., Rinaldi, L., Cascone, C., Mortarino, M., Cringoli, G. (2005): Is heartworm disease really spreading in Europe? Vet. Parasitol. 133, 137–148
7. Knight, D.H., Lok, J.B. (1998): Seasonality of heartworm infection and implications for chemoprophylaxis. Clin. Tech. Small Anim. Pract. 13, 77–82
8. Lok, J.B., Knight, D.H., (1998): Laboratory verification of a seasonal heartworm model. In: Seward, R.L.: Recent Advances in Heartworm Disease. Symposium '98, Am. Heartworm Soc., Batavia, USA, 15–20
9. Slocombe, J.O.D., Surgeoner, G.A., Srivastava, B. (1989): Determination of heartworm transmission period and its use in diagnosis and control. Proc. Heartworm Symposium 1989, Am. Heartworm Soc., Washington D.C., USA, 19–26
10. Molyneux, D.H., Killick-Kendrick, R. (1987): Morphology, ultrastructure and life cycles. In: Peters, W., Killick-Kendrick, R. [eds.]: The Leishmaniasis in Biology and Medicine. Academic Press, London, UK, Vol. 1, 121–176
11. Killick-Kendrick, R. (1990): The life cycle of *Leishmania* in the sandfly with special reference to the form infective to the vertebrate host. Ann. Parasitol. Hum. Comp. 65 (Suppl. 1), 3742
12. Maroli, M., Rossi, L., Baldelli, R., Capelli, G., Ferroglio, E., Genchi, C., Gramiccia, M., Mortarino, M., Pietrobelli, M., Gradoni, L. (2008): The northward spread of leishmaniasis in Italy: evidence from retrospective and ongoing studies on the canine reservoir and phlebotomine vectors. Trop. Med. Int. Health 13, 256–264
13. Ebert, B., Fleischer, B. (2005): [Global warming and spread of infectious diseases.] Bundesgesundheitsbl. Gesundheitsforsch. Gesundheitssch. 48, 55–62
14. Randolph, S.E. (2004): Evidence that climate change has caused 'emergence' of tick-borne diseases in Europe? Int. J. Med. Microbiol. 293 (Suppl. 37), 5–15
15. Lees, A.D., Milne, A. (1951): The seasonal and diurnal activities of individual sheep ticks (*Ixodes ricinus* L.). Parasitol. 41, 189–208
16. Knülle, W., Rudolph, D. (1982): Humidity relationships and water balance of ticks. In: Obenchain, F.D., Galun, R. [eds.]: Physiology of Ticks. Pergamon Press, Oxford, UK, 43–70
17. Needham, G.R., Teel, P.D. (1991): Off-host physiological ecology of ixodid ticks. Ann. Rev. Entomol. 36, 659–681
18. Sonenshine, D.E. (1991): Biology of Ticks. Oxford University Press, Oxford, UK, Vol. 1
19. Randolph, S.E., Storey, K. (1999): Impact of microclimate on immature tick-rodent host interactions (Acari: Ixodidae): implications for parasite transmission. J. Med. Entomol. 36, 741–748
20. Ogden, N.H., St-Onge, L., Barker, I.K., Brazeau, S., Bigras-Poulin, M., Charron, D.F., Francis, C.M., Heagy, A., Lindsay, L.R., Maarouf, A., Michel, P., Milord, F., O'Callaghan, C.J., Trudel, L., Thompson, R.A. (2008): Risk maps for range expansion of the Lyme disease vector, *Ixodes scapularis*, in Canada now and with climate change. Int. J. Health Geogr. 7, 24, doi:10.1186/1476–072X–7–24
21. Korenberg, E.I., Kovalevskii, Y.V. (1999): Main features of tick-borne encephalitis eco-epidemiology in Russia. Zentralbl. Bakteriol. 289, 525–539
22. Glass, G.E., Schwartz, B.S., Morgan, J.M. III, Johnson, D.T., Noy, P.M., Israel, E. (1995): Environmental risk factors for Lyme disease identified with geographic information systems. Am. J. Public Health 85, 944–948
23. Irwin, P.J. (2002): Companion animal parasitology: a clinical perspective. Int. J. Parasitol. 32, 581–593
24. Mellor, P.S., Leake, C.J. (2000): Climatic and geographic influences on arboviral infections and vectors. Rev. Sci. Tech. 19, 41–54
25. Medlock, J.M., Barrass, I., Kerrod, E., Taylor, M.A., Leach, S. (2007): Analysis of climatic predictions for extrinsic incubation of *Dirofilaria* in the United kingdom. Vector Borne Zoonotic Dis. 7, 4–14
26. Tyndall Centre (2005): Key8 for G8. Tyndall Centre for Climate Change Research
27. Svobodova, V., Misonova, P. (2005): The potential risk of *Dirofilaria immitis* becoming established in the Czech Republic by imported dogs. Vet. Parasitol. 128, 137–140
28. Ogden, N.H., Maarouf, A., Barker, I.K., Bigras-Poulin, M., Lindsay, L.R., Morshed, M.G., O'Callaghan, C.J., Ramay, F., Waltner-Toews, D., Charron, D.F. (2006): Climate change and the potential for range expansion of the Lyme disease vector *Ixodes scapularis* in Canada. Int. J. Parasitol. 36, 63–70
29. Harrus, S., Baneth, G. (2005): Drivers for the emergence and re-emergence of vector-borne protozoal and bacterial diseases. Int. J. Parasitol. 35, 1309–1318
30. Epstein, P.R. (2001): West Nile virus and the climate. J. Urban Health 78, 367–371
31. Rappole, J.H., Derrickson, S.R., Hubálek, Z. (2000): Migratory birds and spread of West Nile virus in the Western Hemisphere. Emerg. Infect. Dis. 6, 319–328
32. Desjeux, P. (2001): The increase in risk factors for leishmaniasis worldwide. Trans. R. Soc. Trop. Med. Hyg. 95, 239–243
33. Barrett, T.V., Senra, M.S. (1989): Leishmaniasis in Manaus, Brazil. Parasitol. Today 5, 255–257
34. Aguilar, C.M., Fernández, E., Fernández, R., Cannova, D.C., Ferrer, E., Cabrera, Z., Souza, W.J., Coutinho, S.G. (1998): Urban visceral leishmaniasis in Venezuela. Mem. Inst. Oswaldo Cruz 93, 15–16
35. Bowman, D. (2007): Spread of companion animal vector-borne parasitic disease in the US and Europe: Concerns relative to travel, national disasters, shelter-source animals and wildlife. Proc. 2nd Canine Vector-Borne Disease (CVBD) Symposium, Sicily, Italy, April 25.–28., 2007, 16–23
36. Greer, A., Ng, V., Fisman, D. (2008): Climate change and infectious diseases in North America: the road ahead. CMAJ 178, 715–722

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