Chapter 13

Impact of Climate Change on Zoonotic Diseases in Latin America

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http://dx.doi.org/10.5772/50605

1. Introduction

The United Nations Framework Convention on Climate Change (UNFCC), located in Bonn, Germany, defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of global atmosphere and which is in addition to natural climate variability observed over comparable time periods". Although many other definitions can be found and have been stated by many authors and research groups, the important key message, is that global climate change poses a serious threat to the World, which can generate social upheaval, population displacement, economic hardships, and environmental degradation, among many other relevant consequences. In order to reach a green as less anthropogenically impacted World, according to the new ecological trends in the society, mitigation of global climate change should be a priority for the society and its governments (Rodriguez-Morales, 2011).

As has been previously stated, climate change is already a widely known problem to multiple disciplines (Rodriguez-Morales, 2005). Although its origins can converge in a complex of multiple interacting phenomena, for some disciplines, such as biological and medical sciences, their consequences are more studied and highlighted for their current and further implications. Even more, its impacts and squeals are cause of concern at a global level (Rodriguez-Morales et al, 2010). This growing threat represents in the XXI century a significant challenge for the humankind. Its effects even include many aspects that have been not studied by the society at different levels.

Right now, there is now no serious scientific debate: human actions are changing the world's climate, and are set to do so at an increasing rate in coming decades (McMichael et al, 2012; Rahmstorf, 2010; Meinshausen et al, 2009). Urgent action is now required to reduce emissions of carbon dioxide (the dominant long acting greenhouse gas); if global temperature rises are not to exceed 2°C—the International Energy Authority warns that "the door to 2°C is closing"

(International Energy Agency, 2011). Indeed, emissions must be hugely curtailed within just two decades, and then zero net emissions achieved by later this century, assisted by increased biosequestration of carbon dioxide from the atmosphere (Friedlingstein et al, 2011). However, emissions continue to rise, having increased by 49% since 1990 and by an accelerated annual rate of 5.9% in 2010 (McMichael et al, 2012; Peters et al, 2012).

In the context of the multiple impacts that climate change can pose in the World and the society, growing evidence include direct and indirect influences on human health. Good health of the population depends in large magnitude of the delicate balance or interaction between ecological, physical and socioeconomical systems of the biospheres (WHO, 2003). This is one of the many spheres that have been recently highlighted by multiple research reports in regard to the importance of climatic change for global public health (Martens et al, 1997, Rodriguez-Morales et al, 2010, Rodriguez-Morales, 2011). The role that climate change may play in altering human health, particularly in the emergence and spread of diseases, is an evolving area of research, that is even being so more complex and specialized year to year (Hambling et al, 2011). It is important to understand this relationship because it will compound the already significant burden of diseases on national economies and public health, although many times limited for some of them, such as zoonotic diseases. Authorities need to be able to assess, anticipate, and monitor human health vulnerability to climate change, in order to plan for, or implement action to avoid these eventualities (Hambling et al, 2011).

In some regions of the World numerous populations will be displaced by the increase of the level of the sea or will be seriously affected by droughts and famines, decrease of suitable lands for the agriculture, increase of the food-borne diseases, water-borne diseases, vector-borne diseases as well increase of premature deaths and diseases related to the air pollution (Mills, 2009; PAHO, 2008; United Nations, 2006; Diaz, 2006).

In this context infectious diseases have been highlighted, however in the scope of them, impact of climate change on zoonotic diseases has been largely neglected. Although these emerging conditions are very prone to increase due to shifts in the distribution and behaviour of vectors and animal species, which indicates that biologic systems are already adapting to ecological variations, more research is still necessary to fully understand their interacting roles as well how control them.

Zoonotic infections are in general defined as infections transmitted from animal to man (and less frequently vice versa), either directly (through contact or contact with animal products) or indirectly (through an intermediate vector as an arthropod or an insect) (Pappas, 2011). Although the burden of zoonotic infections worldwide is major, both in terms of immediate and long-term morbidity and mortality (Christou, 2011; Akritidis, 2011) and in terms of emergence/reemergence and socioeconomical, ecological, and political correlations (Cascio et al, 2011), scientific and public health interest and funding for these diseases remain relatively minor (Pappas et al, 2012).

Regard the distribution of vectors and pathogens, such as those of malaria and dengue, is clear that climate plays an important role even as a determinant persistence and occurrence at certain places, particularly vulnerable to changes (e.g. in zones of ecological transition in the environmental conditions or ecotones). However, more information is required and necessary for zoonoses, especially those that are important in different regions in the World, such as Leishmaniasis, Chagas disease, Toxocariasis, Brucellosis in Latin America (Rodriguez-Morales et al, 2010).

In this neotropical region recent contributions in the field have demonstrated strong links between climate variability, climate change and emerging and reemerging infectious diseases that represent public health issues for the region. These and other zoonotic diseases represent a significant burden of disease, geographically extended in the region from Mexico in the north to Argentina in the south, including conditions ranging from deserts in the subtropical areas to highlands that are rapidly changing and allowing, for their new climate conditions, the adaptation of vectors and reservoirs that usually were not present there in the past. These varied ecological scenarios have also suffered the impacts of climate change in the socioeconomical systems, such as agriculture and fishing as a consequence of the phases of the El Niño Southern Oscillation (ENSO) phenomena, but also in very specific health conditions such as infectious, tropical and zoonotic diseases such Leishmaniasis, Chagas disease, Toxocariasis, Brucellosis, among others.

Trying to understand these complex relationships between biological and ecological systems in the context of climate change, and its final consequence on human health, different statistical analysis, most of them based on linear regressions, have linked extreme climatic anomalies with significant alterations in the epidemiological patterns of diseases, sometimes coupled directly and indirectly on time and space. Additionally to statistic techniques, geographical information systems (GIS) and remote sensing (spatial epidemiology) have also supported these observations and are currently helping in the developing of systems for prediction and forecasting of such diseases based on climate variability and climate change, as has been previously reported (Rodriguez-Morales et al, 2010; Rodriguez-Morales, 2011) and already in use for tropical diseases such as malaria (Le Sueur et al, 1997; Rodriguez-Morales, 2005; Beck et al, 2000).

In this chapter, an updated review on the evidences about the impact of climate change on zoonotic diseases in Latin America is outlined.

2. General epidemiological and ecological aspects of zoonotic diseases

Emerging zoonotic diseases have increased in importance in human and animal health during the last 10 years, each emerging from an unsuspected quarter and causing severe problems (Benitez et al, 2008; Brown, 2004). Many new emerging and re-emerging diseases are caused by pathogens (bacteria, viruses, parasites) with an animal origin (from different classes and species) and given ecological and temporal conveying. Then, effective surveillance, prevention, and control of zoonotic diseases pose a significant challenge for many countries (Meslin et al, 2000) but are of utmost importance. Particularly in developing countries data record on these diseases is neglected and many times not even done, representing a major barrier to know and understand the epidemiological situation and burden of such diseases. Additionally, given the ecological scenarios where zoonotic diseases arise, different ecoepidemiological aspects need to be incorporated in the analyses, but these, unfortunately, are still not considered by many health agencies, particularly in developing countries.

The burden of zoonotic infections worldwide exceeds involves more than sheer morbidity and mortality, which has been recently analysed for different zoonotic agents by multiple authors (Pappas, 2011; Christou, 2011; Akritidis, 2011). The effect of zoonoses on various parameters of human life can be quantified, e.g. by estimating the economic impact of zoonotic epidemics, which, for the period between 1995 and 2008, exceeded 120 billion dollars in the World (Budke et al, 2006; Cascio et al, 2011). As will be shown later, such epidemiological and social conditions can be directly or indirectly affected by the climatic change (PAHO, 2003; PAHO, 2008; United Nations Development Programme, 2008; United Nations, 2006).

Just to mention some recent figures about the burden of zoonosis in Latin America, in Venezuela, after known outbreaks of acute orally-transmitted Chagas disease beginning in December 2007 (Rodriguez-Morales, 2008), a zoonosis that was considered by many authors as gone (Ache & Matos, 2001), although many reports indicated that never happens (Añez et al, 2004), was again highlighted by scientist and public health authorities, including more care about the report. Then, according to the last National Mortality Report (2009, published in November 2011) (Ministerio del Poder Popular para la Salud, 2011), this zoonosis, also known as American trypanosomiasis (International Code of Diseases, ICD-10, B57), caused the death of 700 persons (a mortality rate of 2.6 deaths/100,000 pop.). In Colombia, according to the National Institute of Health during year 2011, 57,236 exposures to rabies were reported (for a rate of 124.3 events/100,000 pop.) (Instituto Nacional de Salud, 2012). In Perú, the Ministry of Health reported 330 cases of yellow fever, between years 2003 and 2009, for an incidence rate ranging between 15 to 120 cases/100,000 pop (Ministerio de Salud, 2010).

In the last 20 years significant evidences have been generated from multiple science fields demonstrating how the climate change affects directly and indirectly disease vectors (particularly mosquitoes) (Diaz, 2006; Parry et al, 2007), but also animal reservoirs of zoonotic diseases (Benitez et al, 2008; Cardenas et al, 2006; Cardenas et al, 2008). Climate change can accelerate biological development and increase vectors population available to transmit pathogens and diseases as a consequence of its changes on the environment, altitude, cold and heat, and water reservoirs and particularly wetlands (Rodriguez-Morales et al, 2010).

Understanding zoonotic infections as a multifactorial issue is critical, predominantly for preventing their expansion, in terms of geographical and social prevalence. Factors associated with this (either *de novo* or resurfacing) expansion can roughly be categorized as factors related to the pathogens and factors related to human behaviour. These factors are not independent: modifications of human behaviour result in modifications of pathogen ecology and life cycle in more than one pathway (Cascio et al, 2011).

With a more spread and greater population of vectors and reservoirs, disease risk spectrum as a consequence of more time of exposition, is increasing (Rodriguez-Morales et al, 2010; Gubler et al, 1981; Sukri et al, 2003; Rifakis et al, 2005; Halstead, 2006).

3. Climate change and zoonotic diseases in Latin America

3.1. Zoonotic diseases endemic in Latin America

Previously described, it is well established that climate is an important determinant of the distribution of vectors and pathogens (Rodriguez-Morales et al, 2010). This has been extensively described for some tropical non-zoonotic diseases, such as those of malaria (vectorized by *Anopheles spp.* and caused by *Plasmodium falciparum, P. vivax, P. ovale, P. knowlesii*) and dengue (vectorized by *Ae. aegypti* and caused by Dengue viruses) (Rodriguez-Morales, 2009; Herrera-Martinez & Rodriguez-Morales, 2010; Zambrano et al, 2012).. Although not still accepted, recent evidences imply that malaria would be also a zoonotic disease (Lee et al, 2011). In the case of zoonotic diseases, leishmaniasis (vectorized by sandflies *Phlebotomus spp.* [in the Old World] *and Lutzomyia spp.* [in the New World] and caused by *Leishmania spp.*), should be probably the most studied zoonotic disease regard the impacts of climate change and variability in Latin America (Rodriguez-Morales, 2005; Rodriguez-Morales et al, 2010), with available evidences from different countries in the region. However, other zoonoses, such as Chagas disease, with a high burden in many countries, that accounts for close to 20 million people living infected in the region (Von et al, 2007), has been largely neglected regard studies assessing the impact of climate change variability on its epidemiology (Araújo et al, 2009).

Tropical areas of Latin America have been suitable for zoonotic diseases for many years; these are endemic, and climate change now is triggering its increase, persistence, even re-emergence in non-previous endemic areas or in areas where them were eliminated, eradicated or controlled (Benitez et al, 2008). In Table 1 are summarized selected zoonotic diseases that have been reported or are considered endemic in Latin American countries. Some of them have been studied regard the climate variability and climate change impact on their epidemiological patterns (Table 1).

3.2. Evidences regard climate change and its potential effect on disease: Cutaneous and visceral leishmaniasis

In this regard, evidences from Latin America have cumulated useful qualitative and quantitative information that indicates how climate variability and change influenced particularly tropical diseases (McMichael et al, 2003; Arria et al, 2005). In Northeastern Colombia the impacts of El Niño Southern Oscillation climatic fluctuations during 1985–2002 in the occurrence of cases of leishmaniasis in two northeastern provinces of the country (North Santander and Santander) were reported. During that period, it was identified that during El Niño, cases of leishmaniasis increased up to 15.7% in disease incidence in North Santander and 7.74% in Santander, whereas during La Niña phases, leishmaniasis cases decreased 12.3% in Santander and 6.8% in North Santander. When mean annual leishmaniasis cases were compared between La Niña and El Niño years, it was found significant differences for North Santander (p=0.0482) but not for Santander (p=0.0525) (Cárdenas et al, 2006). For the same study period in southern provinces effects of climate variability and change were also studied regard leishmaniasis incidence. In this study 11 southern departments of Colombia were analyzed: Amazonas, Caquetá, Cauca, Huila, Meta, Nariño, Putumayo, Tolima, Valle, Vaupes and Vichada. Climatic data were obtained by satellite and epidemiologic data were obtained from the Health Ministry. National Oceanographic and Atmospheric Administration (NOAA) climatic classification and SOI (Southern Oscillation Index)/ONI (Oceanic Niño Index) indexes were used as indicators of global climate variability. Yearly variation comparisons and median trend deviations were made for disease incidence and climatic variability. During this period there was considerable climatic variability, with a strong El Niño for six years and a strong La Niña for eight. During this period, 19,212 cases of leishmaniasis were registered, for a mean of 4,757 cases/year. Disease in the whole region increased (mean of 4.98%) during the El Niño years in comparison to the La Niña years, but there were differences between departments with increases during El Niño (Meta 6.95%, Vaupes 4.84%), but the rest showed an increase during La Niña (between 1.61% and 64.41%). Differences were significant in Valle (p=0.0092), Putumayo (p=0.0001), Cauca (p=0.0313), and for the whole region (p=0.0023), but not in the rest of the departments (Cárdenas et al, 2008). These informations show how climatic changes influence the occurrence of leishmaniasis in northeastern and southern Colombia.

Similar results have been described in Venezuela. Between 1994 and 2003, an study in 2,212 cases of cutaneous leishmaniasis cases also linked climate variability to disease incidence in an endemic area of the country, Sucre state. During that period, three important El Niño phases were observed: 1994-1995, 1997-1998, and 2001-2003, being the one in 1997-1998 the most relevant one, which was followed by a chilly and rainy season in 1999 (La Niña). During 1999-2000, 360 cutaneous leishmaniasis cases were recorded in Sucre, with an important variability within a year, and a 66.7% increase in cutaneous leishmaniasis cases (F=10.06, p=0.0051) associated with the presence of a weak La Niña phenomenon (not too cold and rainy). Models showed that with higher Southern Oscillation Index (SOI) values, there was a reduced incidence of cutaneous leishmaniasis (r^2=0.3308; p=0.0504). The increase with respect to the average trend in rain was associated with increases in trends for cutaneous leishmaniasis in the period from 1994 to 2003 (p=0.0358) (Cabaniel et al, 2005).

Although not described in such detail, in Suriname cutaneous leishmaniasis is a seasonal disease. The rainy seasons are from November to January and from May to July. In a recent study (2008), most patients with disease were registered during the short dry season in March (35%) (van der Meide et al, 2008). In Brazil studies made on leishmaniasis vector have characterized spatial distribution of them. In Mato Grosso, the vector sandfly *Lu. whitmani* s.l. have been positively correlated with deforestation rates and negatively correlated with the Brazilian index of gross net production (IGNP), a primary indicator of socio-economic development. Authors found that favourable habitats occur in municipalities with weaker economic development which confirms that vector occurrence is linked to precarious living conditions, found either in rural settlements of the Brazilian government's agrarian reform program, or in municipalities with intense migratory flows of people from lower social levels (Zeilhofer et al, 2008). In Colombia, another entomological study in 5,079 sandflies collected (*Lu. spinicrassa* represented 95.2% of them) have linked population densities to climate. The climatic period where the collection of vectors was done corresponded to a dry season of El Niño (highest Oscillation Niño Index in the last 2006 trimester). In general, the main components analyses evidenced a significant inverse relation between *Lu. spinicrassa* abundance and the relative humidity ($p<0.05$), as well also with the rainfall ($p<0.05$), but not for the average temperature ($p>0.05$) (Galvis et al, 2009). In Costa Rica and Bolivia, recent studies have also linked social and climate changes with cutaneous leishmaniasis (Chaves and Pascual, 2006; Gomez et al, 2006).

Disease	**Present in Latin America**	**Studies have shown climate variability impact on disease**
Anthrax	Yes	Yes, but not in Latin America (Joyner et al, 2010)
Babesiosis	Yes (Montenegro-James, 1992)	Yes, but not in Latin America (Hoch et al, 2012)
Balantidiasis	Yes	No
Barmah Forest virus	No	Yes, but not in Latin America (Naish et al, 2009)
Bartonellosis	Yes	Yes (Chinga-Alayo et al, 2004)
Bilharzia or schistosomiasis	Yes	Yes, but not in Latin America (Mas-Coma et al, 2009)
Bolivian hemorrhagic fever	Yes	No
Borreliosis (Lyme disease and others)	Yes (Santos et al, 2011)	No
Bovine tuberculosis	Yes	No
Brucellosis	Yes	No
Campylobacteriosis	Yes	Yes, but not in Latin America (Kovats et al, 2005)
Chagas disease	Yes	No
Cholera	Yes	Yes (Lama et al, 2004)
Cowpox	Yes (Megid et al, 2008)	No
Creutzfeldt-Jakob disease (vCJD)	Yes	No
Cryptosporidiosis	Yes	Yes, but not in Latin America (Britton et al, 2010)
Cutaneous larva migrans	Yes	No
Eastern equine encephalitis virus	Yes	No
Echinococcosis	Yes	No

Disease	Present in Latin America	Studies have shown climate variability impact on disease
Erysipeloid	Yes	No
Fasciolosis	Yes	No
Giardiasis	Yes	Yes (Hermida et al, 1990)
H1N1 influenza	Yes	No
Hantavirus	Yes	Yes (Magrin et al, 2007)
Leishmaniasis	Yes	Yes (see section 3.2)
Leptospirosis	Yes	Yes, but not in Latin America (Codeço et al, 2005)
Listeriosis	Yes	No
Lymphocytic choriomeningitis virus infection	No	No
Paragonimiasis	Yes	No
Rabies	Yes	Yes (Rifakis et al, 2006)
Rift Valley fever	No	Yes (Hightower et al, 2012)
Rotavirus diarrhea	Yes	Yes, but not in Latin America (Hashizume et al, 2008)
Salmonellosis	Yes	No
Sparganosis	Yes (Moulinier et al, 1982)	No
Streptococcus suis infection	Yes (Costa et al, 1995)	No
Toxocariasis	Yes (Delgado & Rodriguez-Morales, 2009)	No
Toxoplasmosis	Yes	No
Trichinosis	Yes	No
Tularemia	Yes (Machado-Ferreira et al, 2009)	No
Venezuelan equine encephalitis virus	Yes	No
Venezuelan hemorrhagic fever	Yes	No
West Nile virus	Yes (Bosch et al, 2007)	Yes, but not in Latin America (Ruiz et al, 2010)
Western equine encephalitis virus	Yes (Ruiz-Gomez & Espinosa, 1981)	Yes, but not in Latin America (Sellers & Maarouf, 1988)
Yellow fever	Yes	Yes (Vasconcelos et al, 2001; Rodriguez-Morales et al, 2004).
Yersiniosis	Yes	Yes, but not in Latin America (Ari et al, 2010)

Table 1. Selected zoonoses present in Latin America and which of them have been studied regard the impact of climate variability and climate change on disease epidemiology.

In the case of visceral leishmaniasis, also studies in Latin America have linked its incidence to climate. Prolonged droughts in semi-arid north-eastern Brazil have provoked rural-urban migration of subsistence farmers, and a re-emergence of visceral leishmaniasis (Confalonieri, 2003). A significant increase in visceral leishmaniasis in Bahia State (Brazil) after the El Niño years of 1989 and 1995 has also been reported (Franke et al, 2002).

Besides these reports, there are no more recent studies and in other countries in Latin America, indicating the impact and importance of climate change on the epidemiology of leishmaniasis.

3.3. Evidences regard climate change and its potential effect on disease: Other zoonotic parasitic diseases

Other zoonotic parasitic diseases, such as schistosomiasis have been linked to climate variability (Kelly-Hope & Thomson, 2008), although no specifically in Latin America (Mas-Coma et al, 2009). Closely to leishmaniasis, other parasitic zoonotic disease extensively present in the region is Chagas disease, however, although probably will be influenced by climate change, there are no specific studies addressing this important aspect. Zoonotic parasite diseases that have been studied regard the impact of climate change in their epidemiology, now include (Table 1): babesiosis (Hoch et al, 2012) (influences not yet studied for Latin America), cryptosporidiosis (Britton et al, 2010) (influences not yet studied for Latin America), giardiasis (Hermida et al, 1990) (Table 1).

Although many others, according to their ecology and related environmental aspects would be suitable and susceptible to be affected by climate change and variability, evidences have been not yet generated (Table 1).

3.4. Evidences regard climate change and its potential effect on disease: Viral zoonotic diseases

Some viral zoonotic diseases in Latin America have been linked to climate variability and climate change. This is the case of rabies, hantavirus and yellow fever, among others such as H1N1 influenza and other viral haemorrhagic fevers that probably are susceptible to climate change impact. An study between 2002-2004 linked rabies occurrence in Venezuela to climate variability. Rabies in Venezuela has been important in last years, affecting dogs, cats, and human, among other animals, being a reportable disease. In Zulia state, it is considered a major public health concern. Recently, a considerable increase in the incidence of rabies has been occurring, involving many epidemiological but also ecoepidemiological and social factors. These factors were analyzed in 416 rabies cases recorded during the study period. Incidence has been increasingly significantly, affecting mainly dogs (88.94%). Given this epidemiology it was associated ecoepidemiological and social factors with rabies incidence in the most affected state, Zulia. This area has varied environmental conditions. It is composed mostly of lowlands bordered in the west by mountain system and in the south by the Andes. The mean temperature is 27.8ºC, and mean yearly rainfall is 750 mm.

Climatologically, year 2002 corresponded with El Niño (drought), middle 2003 evolved to a Neutral period, and 2004 corresponded to La Niña (rainy); this change may have affected many diseases, including rabies. Ecological analysis showed that most cases occurred in lowland area of the state and during rainy season ($p<0.05$) (Rifakis et al, 2006). For hantaviruses, outbreaks of hantavirus pulmonary syndrome have been reported for Argentina, Bolivia, Chile, Paraguay, Panama and Brazil after prolonged droughts (Williams et al., 1997; Magrin et al, 2007), probably due to the intense rainfall and flooding following the droughts, which increases food availability for peri-domestic (living both indoors and outdoors) rodents (Magrin et al, 2007). In Brazil and Venezuela, yellow fever outbreaks have been linked to climate variability (Vasconcelos et al, 2001; Rodriguez-Morales et al, 2004) (Table 1).

3.5. Evidences regard climate change and its potential effect on disease: Bacterial zoonotic diseases

Bacterial infections have been also linked to an increase related to climate variability, climate change and global warming (Table 1). Zoonotic bacteria, such as *Leptospira* has been also linked to climate variability. Flooding produces outbreaks of leptospirosis in Brazil, particularly in densely populated areas without adequate drainage (Kupek et al, 2000). In 1998, increased rainfall and flooding after hurricane Mitch in Nicaragua, Honduras, and Guatemala caused a leptospirosis outbreak, and an increased number of cases of malaria, dengue fever, and cholera (Costello et al, 2009). In Perú, one of the non-zoonotic forms of bartonellosis, Carrion's disease (*Bartonella bacilliformis*) has been linked also to climate variability (Huarcaya et al, 2004). *Vibrio cholerae* is another zoonotic bacterial pathogen in which its incidence has been linked to climate variability. As ocean temperatures rise with global warming and more intense El Niños, cholera outbreaks might increase as a result of more plankton blooms providing nutrients for *Vibrio cholerae*. Studies in Peru, Ecuador, Colombia, Mexico and Venezuela have evidenced these relationships (Patz et al, 2005; Farfan et al, 2006; Chavez et al, 2005; Franco et al, 1997; Lama et al, 2004).

As shown in table 1, many other zoonotic bacterial agents would be affected by climate change, but evidences have been not yet generated in Latin America regard them, such as: anthrax (Joyner et al, 2010), borreliosis (lyme disease and others), bovine tuberculosis, brucellosis, campylobacteriosis (Kovats et al, 2005), listeriosis, *Mycobacterium marinum* infection, salmonellosis, *Streptococcus suis* infection, tularemia and yersiniosis (Ari et al, 2010).

3.6. Evidences regard climate change and its potential effect on disease: Other zoonoses

For veterinary public health, climate may be associated with seasonal occurrence of diseases in animals rather than with spatial propagation (Table 1). This is the case for pathogens or parasitic diseases, such as fascioliasis, in areas with higher temperatures, when seasonality is extended as a consequence of the increased survival of the parasite outside the host or, conversely, shortened by increased summer dryness that decreases their numbers. For other pathogens, such as parasites that spend part of their life cycle as free stages outside the host, temperature and humidity may affect the duration of survival. Climate change could modify the rate of development of parasites, increasing in some cases the number of generations and then extending the temporal and geographical distribution. New World screwworm is frequently found in South America, with infestations increasing in spring and summer and decreasing in autumn and winter (Rodriguez-Morales, 2006; Paris et al, 2008). West Nile Virus is a disease in which both long-distance bird migration and insect population dynamics (*Culex*) are driven by climate conditions. Vesicular stomatitis (VS) affects horses, cattle and pigs and is caused by various vesiculoviruses of the family Rhabdoviridae. Seasonal variation is observed in the occurrence of VS: it disappears at the end of the rainy season in tropical areas and at the time of the first frosts in temperate zones (Pinto et al, 2008).

3.7. Climate change and zoonotic diseases: Public health perspectives

Given the substantial burden of already studied zoonotic disease associated to climate change in developing tropical countries, such as most of Latin America, it is of utmost relevance to incorporate climate changes into public health thinking, including not only at health authorities and systems, but also in the whole public health education and faculties. However, as shown in Table 1, many diseases are still neglected regard the study of climate change impact on them, and deserve immediate analyses in order to establish their magnitude and relevance.

Although many studies still may have some limitations such as a lack of incorporation of other meteorological factors into the analysis (temperature, rainfall, sun radiation, transpiration or evotranspiration, relative humidity, vegetation indexes [Normalized Difference Vegetation Index, NDVI and Enhanced Vegetation Index, EVI] among others) (Cárdenas et al, 2006), as well more deep analyses, it has been suggested that such findings are relevant from a public health perspective to better understand the ecoepidemiology of different communicable diseases (Rodriguez-Morales, 2005; Rodriguez-Morales et al, 2010).

However, further research is needed in this region and in other endemic areas to develop monitoring systems that will assist in predicting the impact of climate changes in the incidence of tropical diseases in endemic areas with various biological and social conditions.

4. Conclusions

Given the substantial burden of zoonotic disease associated to climate change in developing tropical countries, such as most of Latin America, it is of utmost relevance to incorporate climate changes into public health thinking and prevention. Although many studies still may have some limitations such as a lack of incorporation of other meteorological factors into the analysis, it has been suggested that such findings are relevant from a public health perspective to better understand the ecoepidemiology of different diseases.

Global warming is an ecological emergency, but its implications for human disease caused by zoonotic infectious agents remains understudied. Animals' migration may be affected by global temperature alterations, they could seek novel migratory routes that may also transfer a novel zoonosis to a previously non-endemic area, as has been previously reported particularly in birds (Cascio et al, 2011).

Further research is needed in the World, and particularly in Latin America and specially in endemic areas and countries for each specific zoonotic disease to develop monitoring systems that will assist in predicting the impact of climate changes in the incidence of zoonotic diseases in endemic areas with various biological and social conditions.

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