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# Impact of Climate Change on Zoonotic Diseases in Latin America

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Additional information is available at the end of the chapter

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

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## 1. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC), 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 (Rodríguez-Morales, 2011).

As has been previously stated, climate change is already a widely known problem to multiple disciplines (Rodríguez-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 (Rodríguez-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 they 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 27.8°C, 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 (Rodríguez-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 (Rodríguez-Morales, 2005; Rodríguez-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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## 5. References

- Aché, A. & Matos, A.J. (2001). Interrupting Chagas disease transmission in Venezuela. *Revista do Instituto de Medicina Tropical de Sao Paulo*, Vol.43, No.1, (January 2001), 37-43.
- Añez, N., Crisante, G. & Rojas, A. (2004) Update on Chagas disease in Venezuela--a review. *Memorias do Instituto Oswaldo Cruz* Vol.99, No.8, (Dec 2004), 781-787.
- Akritidis, N. (2011). Parasitic, fungal and prion zoonoses: an expanding universe of candidates for human disease. *Clinical Microbiology and Infection*, Vol.17, No.3, (January 2011), 331-335.
- Alfaro, W. & Rivera, L. (2008). *Cambio Climático en Mesoamérica: Temas para la creación de capacidades y la reducción de la vulnerabilidad*. The International Development Research Centre (IDRC) y Department for International Development (DFID-UK), London.
- Araújo, C.A., Waniek, P.J., Jansen, A.M. (2009). An overview of Chagas disease and the role of triatomines on its distribution in Brazil. *Vector borne and zoonotic diseases*, Vol.9, No.3, (June 2009) 227-234, ISSN 1530-3667

- Ari TB, Gershunov A, Tristan R, Cazelles B, Gage K, Stenseth NC. Interannual variability of human plague occurrence in the Western United States explained by tropical and North Pacific Ocean climate variability. *Am J Trop Med Hyg*. 2010 Sep;83(3):624-32.
- Arria, M.; Rodríguez-Morales, A.J. & Franco-Paredes, C. (2005). Ecoepidemiología de las Enfermedades Tropicales en Países de la Cuenca Amazónica. *Revista Peruana de Medicina Experimental y Salud Publica*, Vol.22, No.3, (July 2005) 236-240, ISSN 1726-4634
- Barrera, R., Delgado, N., Jimenez M. & Valero S. (2002). Eco-epidemiological factors associated with hyperendemic dengue hemorrhagic fever in Maracay city, Venezuela. *Dengue Bulletin*, Vol.26, No.1, (December 2002) 84–95, ISBN 9290222565
- Beck, L.R., Lobitz, B.M. & Wood, B.L. (2000). Remote sensing and human health: new sensors and new opportunities. *Emerging Infectious Diseases*, Vol.6, No.3, (2000) 217-227, ISSN 1080-6040
- Benítez, J.A., Rodríguez-Morales, A.J., Sojo, M., Lobo, H., Villegas, C., Oviedo, L. & Brown, E. (2004). Descripción de un Brote Epidémico de Malaria de Altura en un área originalmente sin Malaria del Estado Trujillo, Venezuela. *Boletín de Malariología y Salud Ambiental*, Vol.44, No.2, (August 2004) 93-100, ISSN 1690-4648
- Benítez, J.A., Sierra, C. & Rodríguez-Morales, A.J. (2005). Macroclimatic Variations and Ascariasis Incidence in Venezuela. *American Journal of Tropical Medicine & Hygiene*, Vol.73, No.(6 Suppl), (November 2005) 96, ISSN 0002-9637
- Benítez JA, Rodríguez-Morales AJ, Vivas P, Plaz J. (2008). Burden of zoonotic diseases in Venezuela during 2004 and 2005. *Ann N Y Acad Sci*. 2008 Dec;1149:315-7.
- Bosch I, Herrera F, Navarro JC, Lentino M, Dupuis A, Maffei J, Jones M, Fernández E, Pérez N, Pérez-Emán J, Guimarães AE, Barrera R, Valero N, Ruiz J, Velásquez G, Martínez J, Comach G, Komar N, Spielman A, Kramer L. West Nile virus, Venezuela. *Emerg Infect Dis*. 2007 Apr;13(4):651-3.
- Botto, C., Escalona, E., Vivas-Martínez, S., Behm, V., Delgado, L. & Coronel, P. (2005). Geographical patterns of onchocerciasis in southern Venezuela: relationships between environment and infection prevalence. *Parassitologia*, Vol.47, No.1, (March 2005) 145–150, ISSN 0048-2951
- Boutayeb, A. & Boutayeb, S. (2005). The burden of non communicable diseases in developing countries. *International Journal for Equity in Health*, Vol4., No., ( 2005), ISSN 1475-9276
- Britton E, Hales S, Venugopal K, Baker MG. The impact of climate variability and change on cryptosporidiosis and giardiasis rates in New Zealand. *J Water Health*. 2010 Sep;8(3):561-71.
- Brown, C. (2004). Emerging zoonoses and pathogens of public health significance—an overview. *Rev. Sci. Tech*. 23: 435–442.
- Budke CM, Deplazes P, Torgerson PR. (2006). Global socioeconomic impact of cystic echinococcosis. *Emerg Infect Dis* 2006; 12: 296–303.
- Cabaniél, G., Rada, L., Blanco, J.J., Rodríguez-Morales, A.J. & Escalera, J.P. (2005). Impacto de Los Eventos de El Niño Southern Oscillation (ENSO) sobre la Leishmaniosis Cutánea



- en Sucre, Venezuela, a través del Uso de Información Satelital, 1994 - 2003. *Revista Peruana de Medicina Experimental y Salud Pública*, Vol.22, No.1, (January 2005) 32-38, ISSN 1726-4634
- Cárdenas, R., Sandoval, C.M., Rodriguez-Morales, A.J. & Franco-Paredes, C. (2006). Impact of Climate Variability in the Occurrence of Leishmaniasis in Northeastern Colombia. *American Journal of Tropical Medicine & Hygiene*, Vol.75, No.2, (August 2006) 273-277, ISSN 0002-9637
- Cárdenas, R., Sandoval, C.M., Rodriguez-Morales, A.J. & Vivas, P. (2008). Zoonoses and Climate Variability: the example of Leishmaniasis in Southern Departments of Colombia. *Annals of the New York Academy of Sciences*, Vol.1149, No.1, (January 2008) 326-330, ISSN 0077-8923
- Cascio, A., Bosilkovski, M., Rodriguez-Morales, A.J., Pappas, G. (2011). The Socio-Ecology of Zoonotic Infections. *Clin Microbiol Infect* Vol.17, No.3, (Mar 2011) 336-342.
- Céspedes, V.M. (2007). Los desastres, la información y el Centro Latinoamericano de Medicina de Desastres. *ACIMED*, Vol.16, No.2, (2007) 0-0, ISSN 1024-9435
- Chaves, L. F. & Pascual, M. (2006). Climate cycles and forecasts of cutaneous leishmaniasis, a nonstationary vector-borne disease. *Plos Medicine*, Vol.3, No.8, (August 2006) e295, ISSN 1549-1277
- Chavez, M.R.C., Sedas, V.P., Borunda, E.O. & Reynoso, F.L. (2005). Influence of water temperature and salinity on seasonal occurrences of *Vibrio cholerae* and enteric bacteria in oyster producing areas of Veracruz, Mexico. *Marine Pollution Bulletin*, Vol.50, No.12, (December 2005) 1641-1648, ISSN 0025-326X
- Chinga-Alayo E, Huarcaya E, Nasarre C, del Aguila R, Llanos-Cuentas A. (2004). The influence of climate on the epidemiology of bartonellosis in Ancash, Peru. *Trans R Soc Trop Med Hyg*. 2004 Feb;98(2):116-24.
- Christou, L. (2011). The global burden of bacterial and viral zoonotic infections," *Clinical Microbiology and Infection*, Vol.17, No.3, (January 2011), 326-330
- Codeço CT, Lele S, Pascual M, Bouma M, Ko AI. A stochastic model for ecological systems with strong nonlinear response to environmental drivers: application to two water-borne diseases. *J R Soc Interface*. 2008 Feb 6;5(19):247-52.
- Confalonieri, U. (2003). Variabilidade climática, vulnerabilidade social e saúde no Brasil. *Terra Livre*, Vol.1, No.20, (January 2003) 193-204, ISSN 0102-8030.
- Costa AT, Lobato FC, Abreu VL, Assis RA, Reis R, Uzal FA. Serotyping and evaluation of the virulence in mice of *Streptococcus suis* strains isolated from diseased pigs. *Rev Inst Med Trop Sao Paulo*. 2005 Mar-Apr;47(2):113-5.
- Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., Friel, S., Groce, N., Johnson, A., Kett, M., Lee, M., Levy, C., Maslin, M., McCoy, D., McGuire, B., Montgomery, H., Napier, D., Pagel, C., Patel, J., de Oliveira, J.A., Redclift, N., Rees, H., Rogger, D., Scott, J., Stephenson, J., Twigg, J., Wolff, J. & Patterson, C. (2009). Managing the health effects of climate change Lancet and University College London Institute for Global Health Commission. *Lancet*, Vol.373, No.9676, (May 2009) 1693-1733, ISSN 0140-6736

- Delgado, O. & Rodríguez-Morales AJ. Aspectos clínico-epidemiológicos de la toxocariasis: una enfermedad desatendida en Venezuela y América Latina. *Boletín de Malariología y Salud Ambiental* 2009 Ene/Jul; 49(1):1-33.
- Depradine, C. & Lovell, E. (2004). Climatological variables and the incidence of Dengue fever in Barbados. *International Journal of Environmental Health Research*, Vol.14, No.6, (December 2004) 429–441, ISSN 0960-3123
- Diaz, J.H. (2006). Global climate changes, natural disasters, and travel health risks. *Journal of Travel Medicine*, Vol.13, No.6, (November 2006), 361-72, ISSN 1195-1982
- Ebi, K.L. & Paulson, J.A. (2007). Climate change and children. *Pediatrics Clinics of North America*, Vol.54, No.2, (April 2007) 213-226, ISSN 0031-3955
- Ebi, K. Climate change and health risks: assessing and responding to them through 'adaptive management'. *Health Aff (Millwood)*. 2011 May 30;924-30.
- Farfan, R., Gomez, C., Escalera, J.P., Guerrero, L., Aragundy, J., Solano, E., Benitez, J.A., Rodríguez-Morales, A.J. & Franco-Paredes C. (2006). Climate Variability and Cholera in the Americas. *International Journal of Infectious Diseases*, Vol.10, No.Suppl 1, (June 2006) S12-S13, ISSN 1201-9712
- Fernando, J., Brunstein J., Fernando, J. & Jankilevich, S.S. (2001). *Disyuntivas para el diseño de políticas de mitigación de la contaminación atmosférica global y local. El caso de la Ciudad de Buenos Aires. Documento de Trabajo N° 69*, Universidad de Belgrano, Buenos Aires.
- Franke, C.R., Ziller, M., Staubach, C. & Latif, M. (2002). Impacts of the El Niño/Southern Oscillation on visceral leishmaniasis, Brazil. *Emerging Infectious Diseases*, Vol.8, No., (September 2002) 914-917, ISSN 1080-6040
- Friedlingstein, P., Solomon, S., Plattner, G.-K., Knutti, R., Ciais, P., Raupach, M.R. (2011) Long-term climate implications of twenty-first century options for carbon dioxide emission mitigation. *Nature Climate Change*, Vol.1, 457-461.
- Galvis-Ovallos, F., Espinosa, Y., Gutiérrez-Marín, R., Fernández, N., Rodríguez-Morales, A.J. & Sandoval, C. (2009). Climate variability and *Lutzomyia spinicrassa* abundance in an area of cutaneous leishmaniasis transmission in Norte de Santander, Colombia. *International Journal of Antimicrobial Agents*, Vol.34, No.Suppl 2, (July 2009) S4, ISSN 0924-8579
- Gomez, C., Rodríguez-Morales, A.J. & Franco-Paredes, C. (2006). Impact of Climate Variability in the Occurrence of Leishmaniasis in Bolivia. *American Journal of Tropical Medicine & Hygiene*, Vol.75, No.(5 Suppl), (November 2006) 42, ISSN 0002-9637
- Gubler, D.J., Suharyono, W., Lubis, I., Eram, S. & Gunarso, S. (1981). Epidemic dengue 3 in central Java, associated with low viremia in man. *American Journal of Tropical Medicine & Hygiene*, Vol.30, No.5, (September 1981) 1094-1099, ISSN 0002-9637
- Gubler DJ, Reiter P, Ebi KL, Yap W, Nasci R, Patz JA. (2001). Climate variability and change in the United States: potential impacts on vector- and rodent-borne diseases. *Environ Health Perspect*. 2001 May;109 Suppl 2:223-33.

- Hambling, T., Weinstein, P., Slaney, D. (2011). A review of frameworks for developing environmental health indicators for climate change and health. *Int J Environ Res Public Health* Vol.8, No.7, (July 2011) 2854-2875.
- Halstead, S.B. (2006). Dengue in the Americas and Southeast Asia: do they differ? *Revista Panamericana de Salud Publica*, Vol.20, No.6, (December 2006) 407-415, ISSN 1020-4989
- Hashizume M, Armstrong B, Wagatsuma Y, Faruque AS, Hayashi T, Sack DA. Rotavirus infections and climate variability in Dhaka, Bangladesh: a time-series analysis. *Epidemiol Infect.* 2008 Sep;136(9):1281-9.
- Hermida RC, Ayala DE, Arróyave RJ. Circannual incidence of *Giardia lamblia* in Mexico. *Chronobiol Int.* 1990;7(4):329-40.
- Herrera-Martinez, A.D. & Rodriguez-Morales, A.J. (2010). Potential Influence of Climate Variability on Dengue Incidence Registered in a Western Pediatric Hospital of Venezuela. *Tropical Biomedicine*, Vol.27, No.2, (August 2010) 280-286, ISSN
- Hightower A, Kinkade C, Nguku PM, Anyangu A, Mutonga D, Omolo J, Njenga MK, Feikin DR, Schnabel D, Ombok M, Breiman RF. Relationship of climate, geography, and geology to the incidence of Rift Valley fever in Kenya during the 2006-2007 outbreak. *Am J Trop Med Hyg.* 2012 Feb;86(2):373-80.
- Hoch T, Goebel J, Agoulon A, Malandrin L. (2012). Modelling bovine babesiosis: A tool to simulate scenarios for pathogen spread and to test control measures for the disease. *Prev Vet Med.* 2012 Feb 15.
- Huarcaya, E., Chinga, E., Chávez, J.M., Chauca, J., Llanos, A., Maguiña, C., Pachas, P. & Gotuzzo, E. (2004). Influencia del fenómeno de El Niño en la epidemiología de la bartonelosis humana en los departamentos de Ancash y Cusco entre 1996 y 1999. *Revista Médica Herediana*, Vol.15, No., (2004) 4-10, ISSN 1018-130X
- Hurtado-Diaz, M., Riojas-Rodriguez, H., Rothenberg, S., Gomez-Dantes, H. & Cifuentes, E. (2007). Impact of climate variability on the incidence of dengue in Mexico. *Tropical Medicine & International Health*, Vol.12, No.11, (October 2007) 1327-1337, ISSN 1360-2276
- Instituto Nacional de Salud (2012). *Exposición Rábica a semana 52*. Instituto Nacional de Salud (January 2012).
- International Energy Agency. World Energy Outlook November 2011. [www.worldenergyoutlook.org/docs/weo2011/executive\\_summary.pdf](http://www.worldenergyoutlook.org/docs/weo2011/executive_summary.pdf).
- Joyner, T.A., Lukhnova, L., Pazilov, Y., Temiralyeva, G., Hugh-Jones, M.E., Aikimbayev, A., Blackburn, J.K. (2010). Modeling the potential distribution of *Bacillus anthracis* under multiple climate change scenarios for Kazakhstan. *PLoS One.* 2010 Mar 9;5(3):e9596.
- Kelly-Hope, L. & Thomson, M.C. (2008). Climate and Infectious Diseases (Chapter 3), In: *Seasonal Forecasts, Climatic Change and Human Health*, Thomson, M.C., Garcia-Herrera, R. & Beniston, M. (Ed), 31-70, Springer Science, ISBN 978-1-4020-6876-8, New York.
- Koehlmoos TP, Anwar S, Cravioto A. Global health. Chronic diseases and other emergent issues in global health. *Infect Dis Clin North Am.* 2011 Sep 25; 623-38, ix.
- Kovats, S. & Haines, A. (1995). The potential health impacts of climate change: an overview. *Medicine and War*, Vol.11, No.4, (October 1995), 168-78, ISSN 0748-8009

- Kovats RS, Edwards SJ, Charron D, Cowden J, D'Souza RM, Ebi KL, Gauci C, Gerner-Smidt P, Hajat S, Hales S, Hernández Pezzi G, Kriz B, Kutsar K, McKeown P, Mellou K, Menne B, O'Brien S, van Pelt W, Schmid H. Climate variability and campylobacter infection: an international study. *Int J Biometeorol*. 2005 Mar;49(4):207-14.
- Kupek, E., de Sousa Santos Faversoni, M.C. & de Souza Philippi, J.M. (2000). The relationship between rainfall and human leptospirosis in Florianópolis, Brazil, 1991–1996. *Brazilian Journal of Infectious Diseases*, Vol.4, No.3, (June 2000) 131-134, ISSN 1413-8670
- Lama, J.R., Seas, C.R., Leon-Barua, R., Gotuzzo, E. & Sack, R.B. (2004). Environmental temperature, cholera, and acute diarrhoea in adults in Lima, Peru. *Journal of Health, Population and Nutrition*, Vol.22, No.4, (December 2004) 399–403, ISSN 1606-0997
- Lapola, D.M., Oyama, M.D., Nobre, C.A. & Sampaio, G. (2008). A new world natural vegetation map for global change studies. *Anais da Academia Brasileira de Ciências*, Vol.80, No.2, (June 2008) 397-408, ISSN 0001-3765
- Le Sueur, D., Binka, F., Lengeler, C., De Savigny, D., Snow, B., Teuscher, T., Toure, Y. (1997). An atlas of malaria in Africa. *African Health*, Vol.19, No.2, (January 1997), 23-24.
- Lee KS, Divis PC, Zakaria SK, Matusop A, Julin RA, Conway DJ, Cox-Singh J, Singh B. *Plasmodium knowlesi*: reservoir hosts and tracking the emergence in humans and macaques. *PLoS Pathog*. 2011 Apr;7(4):e1002015. Epub 2011 Apr 7.
- Liverman, D. (2009). *Suffering the Science. Climate change, people, and poverty*, Oxfam, ISBN XXXX, Boston
- Machado-Ferreira E, Piesman J, Zeidner NS, Soares CA. Francisella-like endosymbiont DNA and Francisella tularensis virulence-related genes in Brazilian ticks (Acari: Ixodidae). *J Med Entomol*. 2009 Mar;46(2):369-74.
- Magrin, G., Gay García, C., Cruz Choque, D., Giménez, J.C., Moreno, A.R., Nagy, G.J., Nobre, C. & Villamizar, A. (2007). Latin America, In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E., (Ed), 581-615, Cambridge University Press, ISBN 978 0521 88009-1, Cambridge, UK.
- Martens, W.J., Slooff, R. & Jackson, E.K. (1997). Climate change, human health, and sustainable development. *Bulletin of the World Health Organization*, Vol.75, No.6, (1997) 583-588, ISSN 0042-9686
- Mathers, C.D., Loncar, D. (2006) Projections of global mortality and burden of disease from 2002 to 2030. *PLoS Medicine*, Vol.3, No.11, (2006) e442, ISSN
- Mas-Coma S, Valero MA, Bargues MD. Climate change effects on trematodiasis, with emphasis on zoonotic fascioliasis and schistosomiasis. *Vet Parasitol*. 2009 Aug 26;163(4):264-80.
- McMichael, A.J., Campbell-Lendrum, D.H., Corvalan, C.F., Ebi, K.L., Scheraga, J.D. & Woodward, A. (2003). *Climate change and human health. Risk and responses*, World Health Organization, ISBN 92-4-156248-X, Geneva.



- McMichael T, Montgomery H, Costello A. (2012). Health risks, present and future, from global climate change. *BMJ*, Vol.344, (March 2012), e1359.
- Megid J, Appolinário CM, Langoni H, Pituco EM, Okuda LH. Vaccinia virus in humans and cattle in southwest region of Sao Paulo state, Brazil. *Am J Trop Med Hyg*. 2008 Nov;79(5):647-51.
- Meinshausen, M., Meinshausen, N., Hare, W., Raper, S.C.B., Frieler, K., Knutti, R., et al. (2009) Greenhouse-gas emission targets for limiting global warming to 2°C. *Nature*, Vol.458, 1158-1162.
- Meslin, F.X., K. Stohr & D. Heymann. (2000). Public health implications of emerging zoonoses. *Rev. Sci. Tech*. 19: 310–317.
- Mills, D.M. (2009). Climate change, extreme weather events, and us health impacts: what can we say? *Journal of Occupational & Environmental Medicine*, Vol.51, No.1, (January 2009) 26-32, ISSN 1076-2752
- Ministerio de Salud. (2010). *Perú: Incidencia de Fiebre Amarilla*. Ministerio de Salud de Perú, (Diciembre 2010).
- Ministerio del Poder Popular para la Salud. (2011). *Anuario de Mortalidad 2009*. Ministerio del Poder Popular para la Salud de Venezuela, (November 2011).
- Montenegro-James, S. (1992). Prevalence and control of babesiosis in the Americas. *Mem Inst Oswaldo Cruz*. 1992;87 Suppl 3:27-36.
- Moulinier R, Martinez E, Torres J, Noya O, de Noya BA, Reyes O. Human proliferative sparganosis in Venezuela: report of a case. *Am J Trop Med Hyg*. 1982 Mar;31(2):358-63.
- Naish S, Hu W, Nicholls N, Mackenzie JS, Dale P, McMichael AJ, Tong S. Socio-environmental predictors of Barmah forest virus transmission in coastal areas, Queensland, Australia. *Trop Med Int Health*. 2009 Feb;14(2):247-56
- OPS. (2001). *Desigualdades en el acceso, uso y gasto con el agua potable en América Latina y el Caribe*, OPS, Washington, D.C.
- Ortega García, J.A. (2007). El pediatra ante el cambio climático: desafíos y oportunidades. *Boletín de la Sociedad de Pediatría de Asturias, Cantabria, Castilla y León*, Vol.47, No.202, (January 2007) 331-343, ISSN 0214-2597
- PAHO. (1988). *Hippocrates. Airs, waters, places. Pag. 18 Part I Historical development. The challenger of epidemiology. Issues and selected readings*, PAHO, Washington, D.C.
- PAHO. (2003). *Protecting New Health Facilities from Natural Disasters: Guidelines for the Promotion of Disaster Mitigation*, PAHO, ISBN 92 75 124841, Washington, D.C.
- PAHO. (2007). *Health in the Americas 2007. Volume I. Regional. Scientific and Thecnical Publication No. 622*, PAHO, Washington, D.C.
- PAHO. (2008). Climate Change and Disaster Programs in the Health Sector. *Disasters: Preparedness and Mitigation in the Americas*, Vol.110, No.1, (October 2008) 1, 11, ISSN 1564-0701
- Pappas, G. (2011). Of mice and men: defining, categorizing and understanding the significance of zoonotic infections. *Clinical Microbiology and Infection*, Vol.17, No.3, (January 2011), 321–325



- Pappas, G., Cascio, A. & Rodriguez-Morales AJ. The immunology of zoonotic infections. *Clin Dev Immunol* 2012; 2012: 208508
- Paris, L.A., Viscarret, M., Uban, C., Vargas, J. & Rodríguez-Morales, A.J. (2008). Pin-site myiasis: a rare complication of a treated open fracture of tibia. *Surgical Infections*, Vol.9, No.3, (June 2008) 403-406, ISSN 1096-2964
- Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, ISBN 9780521705974, Cambridge, United Kingdom and New York, NY, USA.
- Patz, J.A., Campbell-Lendrum, D., Holloway T. & Foley, J.A. (2005). Impact of regional climate change on human health. *Nature*, Vol.438, No.7066, (November 2005) 310–317, ISSN 0028-0836
- Peters, G.P., Marland, G., Le Quéré, C., Boden, T., Canadell, J.G., Raupach, M.R. (2012). Rapid growth in CO<sub>2</sub> emissions after the 2008-2009 global financial crisis. *Nature Climate Change*, Vol.2, 2-4
- Peterson, A.T., Martinez-Campos, C., Nakazawa, Y. & Martinez-Meyer, E. (2005). Time-specific ecological niche modeling predicts spatial dynamics of vector insects and human dengue cases. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, Vol.99, No.9, (September 2005) 647–655, ISSN 0035-9203
- Pinto, J., Bonacic, C., Hamilton-West, C., Romero, J. & Lubroth J. (2008). Climate change and animal diseases in South America. *Revue scientifique et technique (International Office of Epizootics)*, Vol.27, No.2, (August 2008) 599-613, ISSN 0253-1933
- Poveda, G.J., Rojas, W., Quiñones, M.L., Vélez, I.D., Mantilla, R.I., Ruiz, D., Zuluaga, J.S. & Rua, G.L. (2001). Coupling between annual and ENSO theme scales in the malaria climate association in Colombia. *Environmental Health Perspectives*, Vol.109, No., (May 2001) 489-493, ISSN 0091-6765
- Prüss-Üstün, A. & Corvalán, C. (1988). *Preventing disease through healthy environments*, WHO, Geneva.
- Ramal, C., Vásquez, J., Magallanes, J. & Carey, C. (2009). Variabilidad climática y transmisión de malaria en Loreto, Perú: 1995-2007. *Revista Peruana de Medicina Experimental y Salud Pública*, Vol.26, No.1, (January 2009) 9-14, ISSN 1726-4634
- Rahmstorf, S. (2010) A new view on sea level rise. *Nature Reports Climate Change*, Vol.4, 44-45.
- Rifakis, P., Gonçalves, N., Omaña, W., Manso, M., Espidel, A., Intingaro, A., Hernández, O. & Rodríguez-Morales, A.J. (2005). Asociación entre las Variaciones Climáticas y los Casos de Dengue en un Hospital de Caracas, Venezuela, 1998-2004. *Revista Peruana de Medicina Experimental y Salud Pública*, Vol.22, No.3, (July 2005) 183-190, ISSN 1726-4634
- Rifakis, P.M., Benitez, J.A., Rodriguez-Morales, A.J., Dickson, S.M. & De-La-Paz-Pineda, J. (2006). Ecoepidemiological and social factors related to rabies incidence in Venezuela

- during 2002-2004. *International Journal of Biomedical Science*, Vol.2, No.1, (February 2006) 3-7, ISSN 1550-9702
- Rodríguez-Morales, A.J., Barbella, R.A., Cabaniel, G., Gutiérrez, G. & Blanco J.J. (2004). Influence of Climatic Variations on Yellow Fever Outbreaks In Venezuela, 2002-2003, *Proceedings of 20th Clinical Virology Symposium and Annual Meeting Pan American Society for Clinical Virology*, pp. TM12, ISBN 0000-0000, Clearwater Beach, Florida, USA, april 2004, Pan American Society for Clinical Virology, Clearwater Beach, Florida, USA
- Rodríguez-Morales, A.J. (2005). Ecoepidemiología y Epidemiología Satelital: Nuevas Herramientas en el Manejo de Problemas en Salud Pública. *Revista Peruana de Medicina Experimental y Salud Pública*, Vol.22, No.1, (January 2005) 54-63, ISSN 1726-4634
- Rodríguez-Morales, A.J. (2006). Enfermedades Olvidadas: Miasis. *Revista Peruana de Medicina Experimental y Salud Pública*, Vol.23, No.2, (April 2006) 143-144, ISSN 1726-4634
- Rodríguez-Morales, A.J., Rodríguez, C. & Meijomil P. (2006). Climate Variability Influence and Seasonal Patterns of Gram-positive Cocci Infections in Western Caracas, 1992-2001. *International Journal of Infectious Diseases*, Vol.10, No.Suppl 1, (June 2006) S13-S14, ISSN 1201-9712
- Rodríguez-Morales, A.J. (2008). Impacto potencial para la salud pública latinoamericana del lanzamiento y puesta en órbita del satélite VENESAT-1. *Revista Peruana de Medicina Experimental y Salud Pública*, Vol.25, No.4, (October 2008) 444-445, ISSN 1726-4634
- Rodríguez-Morales, A.J. (2008b). Chagas disease: an emerging food-borne entity?. *Journal of Infection in Deveveloping Countries*, Vol.2, No.2, (April 2008), 149-150.
- Rodríguez-Morales, A.J. (2009). Cambio climático y salud humana: enfermedades transmisibles y América Latina. *Revista Peruana de Medicina Experimental y Salud Pública*, Vol.26, No.2, (April 2009) 268-269, ISSN 1726-4634
- Rodríguez-Morales, A.J., Echezuria, L., Riskey, A. (2010). Impact of Climate Change on Health and Disease in Latin America (Chapter 24). In: Simar S (Editor). *Climate Change and Variability*. Sciyo, Croatia, 463-486, ISBN 9789533071442
- Rodríguez-Morales, A.J. (2011). Climate Change. In: Ogunseitan O (General Editor). *Green Health – An A-toZ Guide [Encyclopedia]*. Robbins P (Series Editor). The SAGE Reference Series on Green Society Toward a Sustainable Future. SAGE Publications, California, USA, 111-115, ISBN 9781412996884
- Rohr JR, Dobson AP, Johnson PT, Kilpatrick AM, Paull SH, Raffel TR, Ruiz-Moreno D, Thomas MB. Frontiers in climate change-disease research. *Trends Ecol Evol*. 2011 Jun;26(6):270-7.
- Ruiz MO, Chaves LF, Hamer GL, Sun T, Brown WM, Walker ED, Haramis L, Goldberg TL, Kitron UD. Local impact of temperature and precipitation on West Nile virus infection in *Culex* species mosquitoes in northeast Illinois, USA. *Parasit Vectors*. 2010 Mar 19;3(1):19.
- Ruiz-Gómez J, Espinosa EL. Serum epidemiology of eastern, western and Venezuelan equine encephalitides in Mexico. *Arch Invest Med (Mex)*. 1981;12(3):395-419.

- Santos M, Ribeiro-Rodrigues R, Talhari C, Ferreira LC, Zelger B, Talhari S. Presence of *Borrelia burgdorferi* "Sensu Lato" in patients with morphea from the Amazonic region in Brazil. *Int J Dermatol*. 2011 Nov;50(11):1373-8.
- Schreiber, K. V. (2001). An investigation of relationships between climate and dengue using a water budgeting technique. *International Journal of Biometeorology*, Vol.45, No.2, (July 2001) 81–89, ISSN 0020-7128
- Sellers RF, Maarouf AR. Impact of climate on western equine encephalitis in Manitoba, Minnesota and North Dakota, 1980-1983. *Epidemiol Infect*. 1988 Dec;101(3):511-35.
- Sukri, N.C., Laras, K., Wandura, T., Didi, S., Larasati, R.P., Rachdyatmaka, J.R., Osok, S., Tjia, P., Saragih, J.M., Hartati, S., Listyaningsih, E., Porter, K.R., Beckett, C.G., Prawira, I.S., Punjabi, N., Suparmanto, S.A., Beecham, H.J., Bangs, M.J. & Corwin, A.L. (2003). Transmission of epidemic dengue hemorrhagic fever in easternmost Indonesia. *American Journal of Tropical Medicine & Hygiene*, Vol.68, No.5, (May 2003) 529-535, ISSN 0002-9637
- Tavares S. (2005). *La bioética, el agua y el saneamiento*, Editorial Disinlimed, Caracas.
- Thong, H.Y. & Maibach, H.I. (2008). Global warming and its dermatologic implications. *International Journal of Dermatology*, Vol.47, No.5, (May 2008) 522-524, ISSN 0011-9059.
- Thomson, M.C., Garcia-Herrera, R. & Beniston, M. (2008). *Seasonal Forecasts, Climatic Change and Human Health*, Springer Science, ISBN 978-1-4020-6876-8, New York.
- United Nations. (2006). *Global Survey of Early Warning Systems*, United Nations, ISBN 9789027725523, New York.
- United Nations Development Programme. (2008). *Fighting climate change: Human solidarity in a divided world*. New York: Oxford University Press; 2006.
- van der Meide, W.F., Jensema, A.J., Akrum, R.A.E., Sabajo, L.O.A., Lai, A., Fat, R.F.M., Lambregts, L., Schallig, H.D.F.H., van der Paardt, M. & Faber, W.R. (2006). Epidemiology of Cutaneous Leishmaniasis in Suriname: A Study Performed in 2006. *American Journal of Tropical Medicine & Hygiene*, Vol.79, No.2, (February 2006) 192-197, ISSN 0002-9637
- Vasconcelos, P.F., Costa, Z.G., Travassos Da Rosa, E.S., Luna, E., Rodrigues, S.G., Barros, V.L., Dias, J.P., Monteiro, H.A., Oliva, O.F., Vasconcelos, H.B., Oliveira, R.C., Sousa, M.R., Barbosa Da Silva, J., Cruz, A.C., Martins, E. C. & Travassos Da Rosa, J.F. (2001). Epidemic of jungle yellow fever in Brazil, 2000: implications of climatic alterations in disease spread. *Journal of Medical Virology*, Vol.65, No.3, (November 2001) 598–604, ISSN 0146-6615
- Von, A., Zaragoza, E., Jones, D., Rodríguez-Morales, A.J., Franco-Paredes, C. (2007). New insights into Chagas Disease: a neglected disease in Latin America. *Journal of Infection in Developing Countries* Vol.1, No.2, (Oct 2007), 99-111.
- WHO. (2003). *Climate change and human health – Risk and responses*, WHO, WMO, PNUMA.
- WHO. (2009). *Facts on climate change and health*, PAHO, Washington, D.C.

- Williams, R.J., Bryan, R.T., Mills, J.N., Palma, R.E., Vera, I. & de Velásquez, F. (1997). An outbreak of hantavirus pulmonary syndrome in western Paraguay. *American Journal of Tropical Medicine & Hygiene*, Vol.57, No.3, (September 1997) 274-282, ISSN 0002-9637
- Woolhouse, M.E. & Gowtage-Sequeria, S. (2005). Host range and emerging and reemerging pathogens. *Emerging Infectious Diseases*, Vol.11, No.12, (December 2005) 1842-1847, ISSN 1080-6040
- Zambrano, L.I., Sevilla, C., Reyes-García, S., Sierra, S., Kafati, R. & Rodriguez-Morales, A J. (2012). Potential impacts of climate variability on Dengue Hemorrhagic Fever in Honduras, 2010. *Tropical Biomedicine*, (accepted in press), ISSN 0127-5720.
- Zeilhofer, P., Kummer, O.P., dos Santos, E.S., Ribeiro, A.L. & Missawa, N.A. (2008). Spatial modelling of *Lutzomyia* (*Nyssomyia*) *whitmani* s.l. (Antunes & Coutinho, 1939) (Diptera: Psychodidae: Phlebotominae) habitat suitability in the state of Mato Grosso, Brazil. *Memorias do Instituto Oswaldo Cruz*, Vol.103, No.7, (November 2008) 653-660, ISSN 0074-0276
- Zell R, Krumbholz A, Wutzler P. Impact of global warming on viral diseases: what is the evidence? *Curr Opin Biotechnol*. 2008 Dec;19(6):652-60.