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Climate change, biodiversity, ticks and tick-borne diseases: The butterfly effect

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ABSTRACT

We have killed wild animals for obtaining food and decimated forests for many reasons. Nowadays, we are burning fossil fuels as never before and even exploring petroleum in deep waters. The impact of these activities on our planet is now visible to the naked eye and the debate on climate change is warming up in scientific meetings and becoming a priority on the agenda of both scientists and policy decision makers. On the occasion of the Impact of Environmental Changes on Infectious Diseases (IECID) meeting, held in the 2015 in Sitges, Spain, I was invited to give a keynote talk on climate change, biodiversity, ticks and tick-borne diseases. The aim of the present article is to logically extend my rationale presented on the occasion of the IECID meeting. This article is not intended to be an exhaustive review, but an essay on climate change, biodiversity, ticks and tick-borne diseases. It may be anticipated that warmer winters and extended autumn and spring seasons will continue to drive the expansion of the distribution of some tick species (e.g., *Ixodes ricinus*) to northern latitudes and to higher altitudes. Nonetheless, further studies are advocated to improve our understanding of the complex interactions between landscape, climate, host communities (biodiversity), tick demography, pathogen diversity, human demography, human behaviour, economics, and politics, also considering all ecological processes (e.g., trophic cascades) and other possible interacting effects (e.g., mutual effects of increased greenhouse gas emissions and increased deforestation rates). The multitude of variables and interacting factors involved, and their complexity and dynamism, make tick-borne transmission systems beyond (current) human comprehension. That is, perhaps, the main reason for our inability to precisely predict new epidemics of vector-borne diseases in general.

1. Introduction

The scientific evidence for rapid climate change is compelling and most experts in the field have now reached a consensus: the Earth's climate is changing. Evidence for this includes increasing global temperature, sea level rise (Fig. 1), warming oceans, shrinking ice sheets, declining Arctic sea ice, glacial retreat, increasing extreme events, ocean acidification, and decreased snow cover (http://climate.nasa.gov/evidence/).

Climate change is modifying the environment where we live and our way of living. For instance, global warming is booming the market for air conditioning, which is expected to grow in the coming decades. The explosive growth of the air conditioning market and the increased fossil fuel burning in response to increased temperatures may contribute to greenhouse gas emissions and, again, to global warming. Indeed, the discovery that chlorofluorocarbons are major contributors to ozone layer breakdown, resulted in their replacement by hydrochlorofluorocarbons and, more recently, by hydrofluorocarbons (Dahl, 2013). Hydrofluorocarbons are better coolants and have no impact on ozone depletion, but they are super-greenhouse gases with high potential to contribute to global warming (Dahl, 2013). Hence, the solution for the ozone layer breakdown is contributing to the greenhouse gas effect. It is like a dog chasing its tail.

Climate change may impact human health and wellbeing in many ways, including by facilitating the spread of many infectious agents. For instance, the changing scenarios of major vector-borne diseases (e.g., malaria, leishmaniasis, Chagas disease) have been linked to several factors, including urbanization and deforestation,

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Fig. 1. Climate change is contributing to sea level rise. The Boa Viagem beach is a tourist destination in Recife, north-eastern Brazil. If current trends in sea level rise persist, cities like Recife may be literally swallowed the sea in the coming decades.

changing demographics in both developing and developed countries, economic crisis, increased global movement of people and animals, and climate change (Colwell et al., 2011). For quite some time, scientists have endeavoured to predict large-scale responses of infectious diseases to climate change (reviewed in Altizer et al., 2013), as many components of the transmission cycles of vector-borne diseases are inextricably tied to climate (Harvell et al., 2002; Altizer et al., 2013). For instance, many blood-feeding arthropods such as ticks spend the bulk of their life cycle in the environment and their development, survival and population dynamics depend on many factors, including host availability, vegetation coverage, and climate (Randolph, 2009; Dantas-Torres, 2010). Climate change may influence tick distribution and density, as well as the risk of tick-borne pathogen transmission to humans (reviewed in Léger et al., 2013).

The climate change debate is warming up in the scientific meetings and becoming a priority on the agenda of both scientists and policy decision makers. On the occasion of the Impact of Environmental Changes on Infectious Diseases (IECID) meeting, held in the 2015 in Sitges, Spain, I was challenged to give a 20-min keynote talk on climate change, biodiversity, ticks and tick-borne diseases. Because 20 min is not enough to deal with such a complex subject, the objective of this article is to logically extend my rationale presented on the occasion of the IECID meeting. This article is not intended to be an exhaustive review, but an essay on climate change, biodiversity, ticks and tick-borne diseases.

2. Our planet, our future

Over the past 4.5 billion years, our planet has passed through ice ages, warmer interglacial periods, such as the present Holocene epoch that began about 10,000 years ago (Thompson, 2010). The planet has also witnessed at least five big mass extinctions (Jablonski, 2002) and, throughout these years, it has shaped its surface, pretty much helped by the world's most dominant species: *Homo sapiens*. Indeed, when our ancestors took the decision to move out from Africa (Shriner et al., 2014), humankind embarked on a journey of no return (Diamond, 1997). In fact, many of the global changes we are witnessing in the present days may be partly attributed to anthropogenic factors.

Since ancient times, humans have killed wild animals for obtaining food and decimated forests for many reasons, including for building villages (...towns, cities, metropolis and megalopolis), crop plantation, cattle grazing, and road construction (Diamond, 1997). And the impact is impressive. Amazingly, it is estimate that over 475 million wild animals (Fig. 2) are killed on Brazilian roads each year (http://cbee.ufla.br/portal/atropelometro/). Furthermore, modern humans are also currently obtaining natural gas and oil by utilizing hydraulic fracturing (Ellsworth, 2013), burning fossil fuels as never before and even exploring petroleum in deep waters (Fisher et al., 2014). The impact of these human activities is unpredictable in the long term, but will certainly influence the course of our existence on Earth.

Tropical deforestation, mainly for grazing cattle and cropland expansion (Morton et al., 2006; Armenteras et al., 2013), creates a drier, hotter climate in the tropics. For instance, land surface acts as a strong global carbon sink and a recent study reported a long-term decreasing trend of the Amazon carbon sink (Brienen et al., 2015), underscoring the importance of preserving tropical forests, not only to protect our global biodiversity but also to mitigate eminent deleterious effects on Earth's climate.

Human development may benefit our way of living today, but also affect our future. All these changes, including our changing behaviour in response to these changes, may affect all kinds of