Using Geographic Information Systems to Analyze the Distribution and Abundance of Aedes aegypti in Africa: The Potential Role of Human Travel in Determining the Intensity of Mosquito Infestation

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ABSTRACT

Increasing attention is being paid to the impact of global climate change on yellow fever and dengue outbreaks. While useful, these studies neglect the role that travel may play in the distribution of Aedes aegypti, the primary vector of both viruses. Even less attention has been paid to the role travel patterns play in affecting the ecology of this vector. To help refocus the debate and illustrate how geographic information systems (GIS) can assist analysis, a global study of Ae. aegypti was digitized. Subsequently, several basic and advanced analyses of the surveys located in Africa were undertaken. Publicly available road data for the continent were included, along with recently published LandScan population data. A novel method for examining correlations within the data at various distances was developed. These correlations were then substantiated using Monte Carlo simulation techniques and found to be significant at p<0.001.

Keywords: Aedes aegypti, Dengue Fever, Ecological Modeling, Geographical Information System (GIS), LandScan, Mosquito Control, Population Ecology, Vector Ecology, Yellow Fever

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INTRODUCTION

Along with other historically significant human infections, such as malaria and typhoid (Gubler et al., 2001; Okawa, 2003), dengue & yellow fever have been and continue to be a tremendous problem throughout much of the developing world (Aiken & Leigh, 1978; Frutaldo et al., 2000; Getis et al., 2003; Gubler et al., 2001; Harrington et al., 2005; Thonnon et al., 1998; Van Benthem et al., 2005). As earth’s climate changes due to global warming, the range of these two deadly diseases will most likely continue to expand. Their primary vector, *Aedes aegypti*, will most likely find a greater geographic range in most regions (Gubler et al., 2001; Julio et al., 2009; Kovats et al., 2001; Monath, 1994; Patz, 1998; Paupy et al., 2005; Shope, 1991; Van Benthem et al., 2005), although there will probably be some contraction in areas as well. In most climate change scenarios, increasing global temperatures and changes in patterns of precipitation will provide new, sustainable environments for populations of the vector (Easterling, 1997; Gubler et al., 2001; Kovats et al., 2001; Patz, 1998; Shope, 1991; Van Benthem et al., 2005). Furthermore, climate models suggest that globally increasing temperatures are expected to make outbreaks of dengue virus more frequent and easier to sustain, especially in temperate regions (Patz, 1998). Such an increase in outbreak duration and geographic range is especially concerning given that dengue is already the most widespread vector borne virus. Taking action against these historically deadly infections requires efforts to substantially reduce or eliminate disease vectors throughout endemic regions. Such a task requires improved surveillance data and methodologies, along with a new commitment to cross-disciplinary study (Kovats et al., 2001; Moore, 2008). Furthermore, the increasing problem of insecticide resistance (da Costa-Ribeiro et al., 2007; Julio et al., 2009; Paupy et al., 2004) makes the need for these improved methods paramount.

Climate factors, such as patterns of precipitation and minimum mean temperature, play a major role in affecting the distribution and abundance of disease vectors worldwide (Aiken & Leigh, 1978; Costanzo et al., 2005; Gubler et al., 2001; Kovats et al., 2001; Reiter, 2001). Without sufficient rain and temperature, disease vector communities cannot sustain themselves overtime (Gubler et al., 2001; Reiter, 2001). In some cases, this is due to changes in mosquito community composition brought on by competition for resources in a drier climate (Costanzo et al., 2005). These abiotic and site specific ecological factors serve as controls on the biological processes needed to sustain vector populations. At a landscape level (Forman and Godron, 1991) these factors can, in fact, determine where endemic disease is and is not possible (Easterling, 1997; Hulme et al., 1998; Kovats et al., 2001; Patz, 1998; Shope, 1991; Van Benthem et al., 2005). Due to the relatively small geographic area over which mosquito populations and communities act (Harrington et al., 2005; Reiter et al., 1995; Spielman & D’Antonio, 2000) researchers often miss how other factors acting within a given climate regime may affect vector ecology (Costanzo et al., 2005; Frutaldo et al., 2000; Getis et al., 2003; Harrington et al., 2005; Kovats et al., 2001; Thonnon et al., 1998). In most of these cases, climate is considered to be the controlling factor for mosquito distribution at the landscape level (Easterling, 1997; Hulme et al., 1998; Kovats et al., 2001; Patz, 1998; Shope, 1991; Van Benthem et al., 2005), and little attention is paid to other factors.

While climate definitely plays a vital role in determining where populations of a vector can and cannot sustain themselves, suggesting that climate, on one hand, or site specific processes, on the other hand, are the only factors affecting vector distribution is inaccurate. Humans also play a significant role in determining the presence or absence of vectors for the diseases that plague them (Aiken & Leigh, 1978; Gubler et al., 2001; Hemme et al., 2010; Paupy et al.,
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