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Supporting local health decision making with spatial video: Dengue, Chikungunya and Zika risks in a data poor, informal community in Nicaragua

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ABSTRACT

One challenge facing spatial scientists trying to support public health outreach and intervention in challenging environments is the lack of fine scale spatial data. These data are required to gain a better understanding of both physical and social systems; *why* disease occurs *where* it does, and *how* to disrupt it. While data options exist, including high resolution aerial imagery, remotely sensed data, and even online mapping products like Google Street View, these all come with limitations. One option that has previously been utilized to assess cholera risk is spatial video. Here it is used to map potential mosquito breeding sites in an endemic Dengue and Chikungunya, and emerging Zika impacted community. We show how this method can provide mapping support in the hands of non-specialist public health workers who, working in collaboration with out-of-area geographic information systems (GIS) teams, can identify where to target limited intervention resources. We use a case study of an impoverished informal style Nicaraguan community suffering from a high disease burden to show spatial variation in potential mosquito breeding habitats. A field team collected street-by-street spatial video data to produce fine scale risk maps of standing water and trash locations, which, when interpreted with the associated spatial video imagery, were used to suggest where intervention strategies should be targeted. We also discuss how these same data layers can be used to address other health concerns traditionally found in informal settlements.

1. Background

Dengue continues to be a problem in many urban environments of Central and South America. This is not the only virus spread by female *A. aegypti* and *Aedes albopictus* mosquitoes, with Chikungunya and most recently Zika being problematic in the same spaces. There has been considerable spatial work, primarily on Dengue, identifying patterns of infection (Dhewantara, Ruliansyah, Fuadiyah, Astuti, & Widawati, 2015; Eisen & Lozano-Fuentes, 2009; Mammen et al., 2008; Morrison, Getis, Santiago, Rigau-Perez, & Reiter, 1998, 2004), and the associated complexities of causation and intervention (Anno et al., 2015; Delmelle, Hagenlocher, Kienberger, & Casas, 2016; Hagenlocher, Delmelle, Casas, & Kienberger, 2013). Dengue in the Americas has increased since the 1970s largely because of lapses in mosquito control (Guzman & Kouri, 2003; Tapia-Conyer, Mendez-Galvan, & Gallardo-Rincon, 2009). While a series of environmental, social, behavioral and even political conditions contribute to mosquito disease risk, resulting in geographic variations across countries, and even within urban areas (Restrepo, Baker, & Clements, 2014), several constants have been identified as causing concern; proximity to water bodies such as canals, an association with poverty (especially in informal settlements), and high human population density (Delmelle et al., 2016; Dickin, Schuster-Wallace, & Elliott, 2014; Hagenlocher et al., 2013; Quintero et al., 2014). Other aspects impacting disease risk include control strategies and behavior modification through

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education (Chaikoolvatana, Singhasivanon, Haddawyc, & Saengnilld, 2013; Chen, Yang, Luo, Yang, & Liu, 2016; Gualberto, Sabines, & Demayo, 2015; Jeelani, Sabesan, & Subramanian, 2015). However, to formulate effective intervention strategies in resource-challenged areas, fine scale spatial data are required (Caprara et al., 2015; Dickin et al., 2014). For example, while proximity to canals *in general* should be considered a risk, the level of risk for each canal is different, and even along sections of the same channel variations will occur; such as if there is increased trash dumping due to a proximate informal settlement, or if water stagnates because of outlet clogging or construction work. The same is true of green spaces. While some studies have shown that community members may be skeptical of all green spaces (for example parks, school grounds, even household plants) because of the possibility of mosquito breeding (Delmelle et al., 2016), the reality is that these risks are not homogenous. Some sections of the park pose greater risks either in terms of trash, or proximity to play areas. Adding further complexity to sub-neighborhood spaces is the role of health care access (Casas, Delmelle, & Delmelle, 2016), and the associated variable of poverty, the combination of which coincide to produce lower surveillance numbers in areas that should probably have a high disease burden (Riley, Ko, Unger, & Reis, 2007). Ironically it is often in the environments where disease risk is greatest, and intervention needed the most, that spatial data are limited or non-existent. There have been various strategies to fill these spatial data gaps for Dengue related research, including volunteered geographic information, participatory geographic information systems (PGIS), community sketch mapping (Dickin et al., 2014), webGIS (Kienberger, Hagenlocher, Delmelle, & Casas, 2013) or utilizing freely available online spatial software such as Google Earth (Chang et al., 2009). Unfortunately, the reality is that for many environments there remains a logistical challenge in acquiring these types of data easily, and for rolling time periods, while ensuring the quality control measures (Haklay, 2010) that would make them useful in helping to inform vector control and public health decision making. When resources are limited, the spatial targeting of education strategies or mosquito reduction is vital, but it is not feasible to blanket cover an entire city or even a neighborhood (Finkelman, 2015). Here we show how Spatial Video (SV from this point on) can be used to create a fine spatial scale risk map for a resource challenged urban area of Nicaragua, known to be endemic for a variety of mosquito-borne diseases, and with little spatial data.

1.1. Mosquito disease concerns in Nueva Vida, Nicaragua

The emergence of Zika in 2015–2016, a new disease transmitted by the same mosquito responsible for Dengue and Chikungunya (WHO, 2016a,b), caused media consternation. While infection with the virus is generally asymptomatic or mild, it has been linked with cases of Guillain-Barre Syndrome in infected individuals and microcephaly in the newborns of women infected during pregnancy (Brasil et al., 2016; Teixeira, Costa Mda, de Oliveira, Nunes, & Rodrigues, 2016). Since its appearance in Brazil, it has followed an expansion path similar to Dengue and Chikungunya (Musso, Cao-Lormeau, & Gubler, 2015; Rabaan, Bazzi, Al-Ahmed, Al-Ghaith, & Al-Tawfiq, 2016). In January 2016 the World Health Organization (WHO) reported that two locally-acquired cases of the Zika virus had been laboratory-confirmed in Nicaragua (WHO, 2016a,b). This emerging threat is particularly troubling for places such as Nueva Vida in Nicaragua, which is part of the larger Ciudad Sandino urban area (population 110,000). This impoverished community already suffers a high disease burden, including endemic Dengue and Chikungunya, and Zika poses yet another challenge to an already overstretched public health system (PAHO, 2016). Other health concerns in the community include poor and nutrient deficient diets resulting in high rates of hypertension, type 2 diabetes, and some heart disease. Additionally, cervical cancer had become a chronic disease issue. Teen pregnancy, asthma (likely from burning trash and indoor stoves), and cuts/scrapes/wounds that become infected are all other topics of concern.

While the Nicaraguan Ministry of Health (MINSA) does fumigate with insecticides on a regular basis, these have proven to have limited efficacy as was witnessed during the Chikungunya outbreak of 2014/2015. Thus, additional vector control and disease prevention strategies are required which have to be both creative and low cost due to the limited available resources.

Valuable information in creating any comprehensive intervention strategy is identifying microhabitats that are suitable for mosquito breeding. Typically for *A. aegypti*, this means sources of standing water, including those created by water storage vessels, discarded plastic containers, trash and tires (Christophers, 1960; Higgs, 2016; Singh et al., 2016). While the WHO recommends eliminating standing water, using mosquito repellant, and installing mosquito nets, in Nueva Vida these things are not perceived to be practical because of a lack of resources in the community (both public and private). Nueva Vida has considerable poverty-related challenges in that it lacks sewage/water treatment services, washing and bath water (referred to as gray water) is typically drained from backyards into the streets, and standing water can be observed throughout the etapas.[1] Therefore, while residents receive information about mosquito related risks with suggestive response actions, for this impoverished community it is unrealistic to believe that health education alone is a practical solution for preventing mosquito-borne diseases. What are required are more effective spatially targeted physical control actions *and* education strategies.

While other data sources such as high resolution aerial imagery, city directories or existing urban spatial data layers may reveal risk features at a general level (Chang et al., 2009; Delmelle et al., 2016), what is often missing are fine scale spatial data that can help reveal the neighborhood specific physical and social processes that contribute to disease risk. For example, the location of standing water or trash accumulation and human activity in and around it, or social gathering points and general cultural activities that increase the likelihood of disease (Chen et al., 2016; Teng, Wu, & Lin, 1999). By knowing these sub-neighborhood spaces and places of risk, especially if enriched by on-the-ground context, more effective intervention strategies can be developed, such as where to send public health or education teams, or even where to place public education notices. Yet for Nueva Vida spatial data is sparse, especially as sections of the community display typical informal settlement characteristics, and as such have no “official” data. To illustrate this situation, consider the map on the right side of Fig. 1 which is one of the only geographic resources available to the local partner organization to identify spaces and places in the study community.

While high resolution imagery has been used elsewhere in Nicaragua to guide mosquito control (Chang et al., 2009), there is no Google Street View for any of the streets in the community. Even if disease data are available to show which of the five etapas has the

[1] The community is split into five *etapas* or stages of the community. Etapas vary in population size and are comprised of blocks or manzanas. The etapas contains mixed land ownership including sections commonly classed as informal settlements, and locally referred to as the green area or area verde. Nueva Vida was originally settled after Hurricane Mitch in 1998 and additional etapas have been added as other natural or man-made disasters have occurred.